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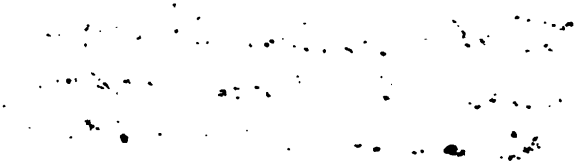
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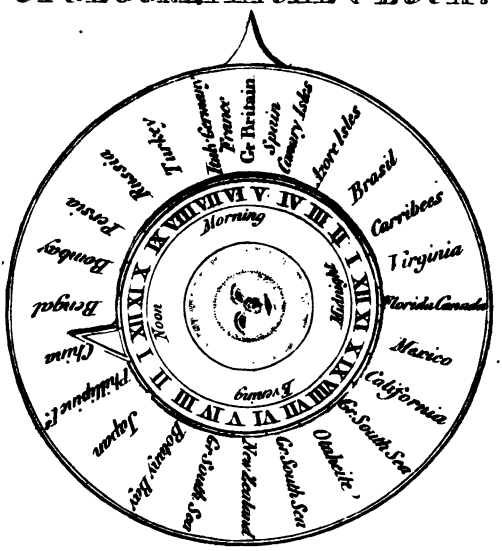


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Shewing the Hour of the Day in any part of the World

AN

INTRODUCTION

TO THE

USE OF THE GLOBES,

FOR

YOUTH OF BOTH SEXES;

PARTICULARLY DESIGNED FOR

SCHOOLS AND PRIVATE TEACHERS.

CONTAINING

Definitions and Problems in Geometry; the Stereographic Projection of the Sphere, Mariner's Compass, &c.; the Rise and Progress of Geography and Astronomy; the Description of the principal Lines on the Globes; fifty Problems on the Terrestrial Globe, and twenty-two on the Celestial, with the Use of the Analemma and Sliding Hour-circle; likewise a Representation and Epitome of the Solar System, Armillary Sphere, Comets, fixed Stars, Constellations, &c. To which is added, a variety of entertaining and useful Paradoxes; with some Questions and Answers by way of Application.

By JOHN GREIG,

PRIVATE TEACHER OF WRITING, GEOGRAPHY, AND PRACTICAL MATHEMATICS.

The Third Edition, Corrected and Enlarged.

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THE following pages have been selected for the express purpose of practical instruction: among the many treatises on this subject, the author, in the course of his teaching, having never met with any one sufficiently calculated for the object in question, and alike remote from the extremes of a mere elementary sketch, and a ponderous, abstruse system, was induced to make the present selection for the use of his own pupils; and, in the hope of its proving equally convenient and advantageous to others, he has now ventured to offer it to the public. He relies on the indulgence of the candid and liberal for any imperfections, or errors, which may be discovered; and will thankfully avail himself of any communication to render it more correct.

It is only necessary to add, that the solutions of the problems are either by calculation, or from Mr. Bardin's new improved globes; and every endeavour has been used to render them as accurate as possible.

The works and authors from which, in the following selection, matter has been taken, or ideas suggested, are the Philosophical Transactions, Encyclo-

pedia, Ferguson, Bonnycastle, M. de Lalande, and Dr. Herschel, on Astronomy; Martin, Dilworth, and Adams, on the Globes; and Gordon's Geographical Grammar; to whose works the author begs leave to refer the reader.

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DIRECTIONS TO THE BINDER.

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III. Solar System 120

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Mr. Greig respectfully informs the heads of Families, and Schools, and the Public in general, in London and its vicinity; that he continues to give lessons in Writing, Arithmetic, Book-keeping, Geometry, Mensuration, Fortification, Navigation, the construction of Mercator's and Stereographic Maps, Geography, Astronomy, the Use of the Globes, &c. at home or abroad. Letters addressed to him at 12, *Bridgewater Street, Somers' Town, will be duly answered.*

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Rule. Set the index, or upper XII, to the given place, and then opposite to any other place on the clock, is the hour required.

When it is noon at Great Britain, what is the hour at Mexico, Otaheite, and Bengal? Answer, 5 at Mexico, nearly 2 at Otaheite in the morning, and 6 in the evening at Bengal.

Prob. II. Any hour and place given, to find what o'clock it is then, at any other place on the clock.

Rule. Set the given hour to the place, and opposite to any other place on the clock is the hour required.

Given 2 in the afternoon at Great Britain, required the hour at the Azores, Great South Sea, and Persia? Answer, noon at the Azores, midnight at the Great South Sea, and 6 in the evening at Persia.

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AN

INTRODUCTION

TO THE

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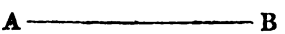
PRACTICAL GEOMETRY.

I. *DEFINITIONS.*

1. Geometry is a science that treats of the properties of magnitudes in general.

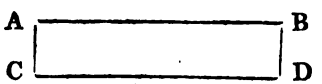
2. All magnitudes are contained by lines.

3. A line has length only, without breadth or thickness, and its extremities are indivisible points, as A B.

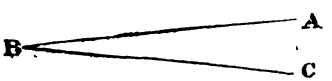


4. A right line is that which is the nearest distance between its points.

5. A superficies is that which consists of length and breadth only, its extremities being lines, as A B D C.



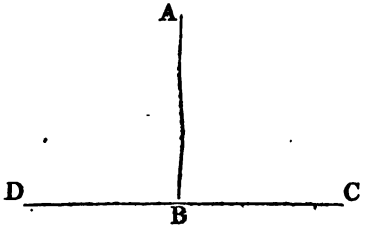
6. A plane angle is the inclination of two right lines which meet in a point, as A B C.



7. An angle is commonly expressed by three letters, the letter that stands in the middle representing the angle, as in the preceding angle, A B C represents the angle; but if there is only one angle in a figure, it may be specified by one letter.

8. A line is perpendicular to another, when it makes the angles on each side equal to one another, as A B is

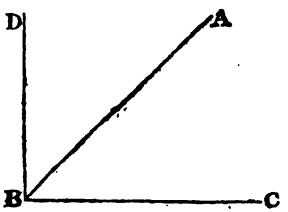
perpendicular to D C, and the angle A B D is equal to the angle A B C.



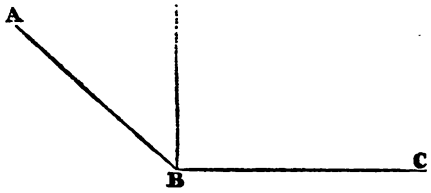
9. A right angle is formed by two lines that stand perpendicular to each other, as A B C.



10. An acute angle is less than a right angle, as A B C is less than C B D.

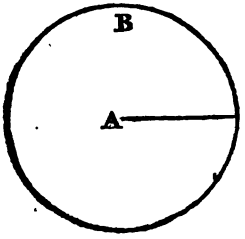


11. An obtuse angle is greater than a right angle, as A B C.



12. A circle is a plane figure formed by the revolution of a right line about one of its ends, which remains fixed, the fixed end is called its centre, as A; and the circular line is called the circumference, as B.

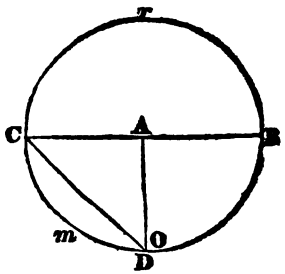
All lines drawn from the centre of a circle to its circumference are equal to one another.



13. The radius of a circle, is any line drawn from the centre to the circumference, as A B, A O, or A C.

14. The diameter of a circle is any line passing through the centre of the circle, both ends terminating in the circumference, as C A B.

15. A chord is any line drawn from one part of the circumference of a circle to another part, not passing through the centre, as C D.



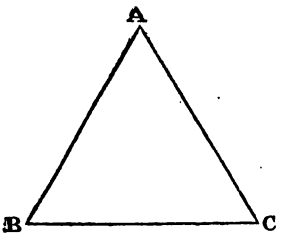
16. A diameter divides a circle into two equal parts, called semicircles, as C A B *r*, and C A B D.

17. A chord line divides a circle into two unequal parts, called segments, as C *r* B D, and C D *m*.

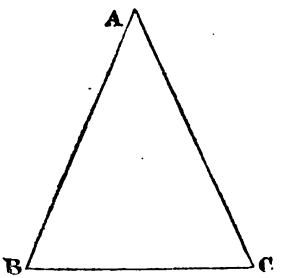
18. A radius, drawn at right angles to the diameter, cuts off a part of the circle, called a quadrant, as A B O.

19. All plane figures, bounded by three right lines, are called triangles.

20. An equilateral triangle has its sides all equal, as A B C; and all its angles are acute.

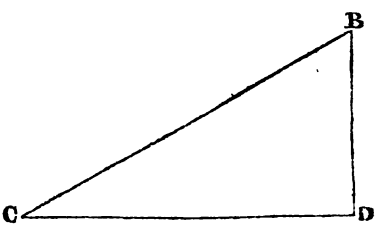


21. An isosceles triangle has two of its sides equal, as A B C.



22. A scalene triangle has all its sides unequal, as B C D.

B C is called the hypothenuse, C D the base, and B D the perpendicular.



In navigation B D is called the difference of latitude, D C the departure from the meridian, B C represents the distance sailed, the rhumb line, or the point of the compass that the ship sails on; and C B D the angle that her course makes with the meridian, B D.

Triangles are likewise described by their angles.

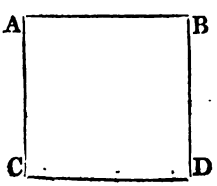
23. A right-angled triangle, has in it one right angle.

24. An obtuse-angled triangle, has in it one obtuse angle.

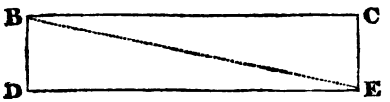
25. An acute-angled triangle, has all its angles acute.

26. All plane figures, bounded by four right lines, are called quadrilaterals.

27. A square is a quadrilateral, having its sides equal, and its angles right angles, as A B D C.



28. A rectangle, oblong square, or parallelogram, has its angles right angles, and its opposite sides are equal and parallel, as B C E D. A line passing from an angle to its opposite angle, in four-sided figures, is called a diagonal, as B E.



29. A rhombus and rhomboid are four-sided figures, whose opposite sides are parallel, but their angles are not right angles.

30. All other four-sided figures, beside those specified, are called trapeziums.

31. Figures having more than four sides are called polygons, and are distinguished by the number of their sides; polygons, of five sides, are called pentagons; of six, hexagons; of seven, heptagons; of eight, octagons, &c.—If their sides and angles are all equal, they are called regular polygons.

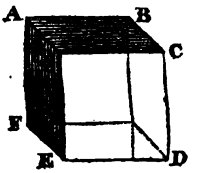
32. Parallel right lines are such, which, if infinitely produced, would never meet, as the lines A B and C D would never meet; but it is evident from the

nature of curves, that if A or B, or both, were produced, they would meet and form a circle; as in nature there is no such thing as a straight line.

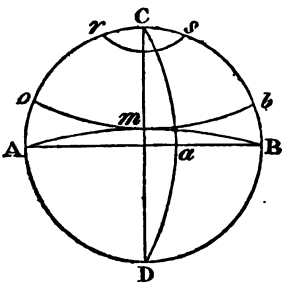
A——————————B

C——————————D

33. A solid has length, breadth, and thickness, and its bounds are superficies, as A B C D E F is a solid cube, bounded by six square sides, which are equal.



34. A sphere is a solid, described by the revolution of a semicircle about its diameter, which is fixed, and represents the artificial globe: the true shape of the earth or natural globe, being an oblate spheroid, that is, flattened towards the poles.



35. The centre of a sphere, or globe, is a point within it, and which is equally distant from every part of its surface.

36. A B represents the equator on a globe.

37. C D represents the brass meridian, C and D the poles, and likewise the zenith and nadir.

38. C *a* D represents a meridian or hour-line.

39. *r s* and *o b* represent parallels of latitude, or *r s* a polar circle, and *o b* a tropic.

40. C B D A represent the horizon, and A *m* B the ecliptic.

Note. The equator, ecliptic, meridians, &c. are named great circles, because they divide the globe into two equal parts, called hemispheres, as A C B and A B D. The tropics, parallels of latitude, and polar circles are called lesser circles, because they divide the globe into unequal parts, called segments, as *o* C *b* and A *o b* B D.

2. *Axioms.**

1. Things which are equal to the same, are equal to one another.

* Axiom, implies a plain, self-evident truth or proposition, which is no sooner proposed but understood. This word is chiefly restrained to mathematics; when otherwise applied, it is frequently called a maxim.

2. If equals be added to equals, the whole are equal.

3. If equals are taken from equals, the remainders are equal.

4. If equals be added to unequals, the whole are unequal.

5. If equals be taken from unequals, the remainder are unequal.

6. Things which are double of the same, are equal to one another.

7. Things which are halves of the same, are equal to one another.

8. Magnitudes which coincide with one another, that is, which exactly fill the same space, are equal to one another.

9. The whole is greater than its part.

10. Two straight lines cannot enclose a space.

11. All right angles are equal to one another.

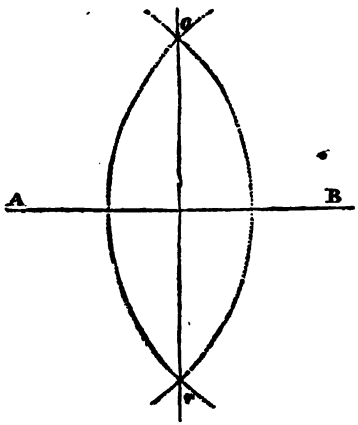
3. *GEOMETRICAL PROBLEMS.*

PROBLEM I.

To divide a given line, A B, *into two equal parts.*

1. With any opening of the compasses greater than half A B, making A and B centres, describe arcs cutting each other in *o r.*

2. Through these points draw the line *o r*, and the point, where it cuts A B, will be the bisection required.

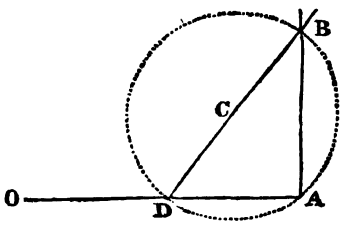


PROBLEM II.

From a given point, A, *in a given line,* O A, *to raise a perpendicular, or to make one line stand at right angles to another line.*

1. With any convenient opening in your compasses, as from A to C, and one point in C, describe a circle, so as to touch the given point, A.

2. Through where the circle cuts the line at D, and the centre C, draw the line B D, from B to A draw the line A B, and it will stand at right angles to O A, and be the perpendicular required.



PROBLEM III.

To draw a line parallel to a given line, A B, *and at a given distance,* C.

1. From any two points in A B, as *s t*, and with a distance in the compasses equal to the given distance, C, describe the arcs *o* and *r*.

2. Through *o* and *r* draw the line D E, so as to touch the extremities of the arcs *o r*, and it will be the parallel line required.



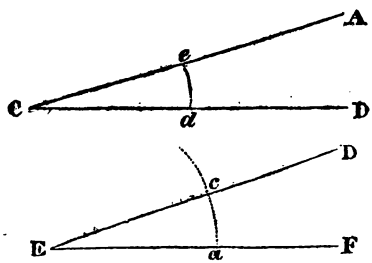
This problem may be more expeditiously performed by a parallel ruler.

PROBLEM IV.

To make an angle equal to another given angle, as A C D.

1. Draw E F, and with any opening of the compasses less than E F, and one point in E, describe the arc *a c*, with the same opening and one point in C, describe the arc *d e*, apply the distance *d e* on the arc *a c* from the line E F.

2. Through E *c* draw the line E D, and the angle D E F will be equal to the angle A C D, as was required.



The lines on the plane scale are marked as follows:

Cho. for the line of chords,
Sin. sines,
Tan. tangents,
S. T. semitangents,
Sec. secants.

PROBLEM V.

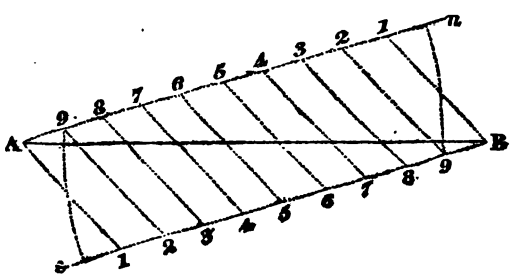
To divide a given line, as A B, *into any number of equal parts, suppose nine equal parts.*

1. From one end of the line, as at A, draw A *n*, of any length, making any angle with A B, and from B draw B *s*, making an angle equal to the angle *n* A B.

2. In the lines A *n* and B *s*, beginning at A and B, with any convenient opening of the compasses, set off as many equal parts as the line is to be divided into, for the annexed figure nine equal parts.

3. Join the divisions A—1, 9—2, 8—3, 7—4, &c. and A B will be divided into nine equal parts, as was required.

Note. B *s* may be more expeditiously found by a parallel ruler, that is, a line drawn parallel to A *n* at the distance *n* B.



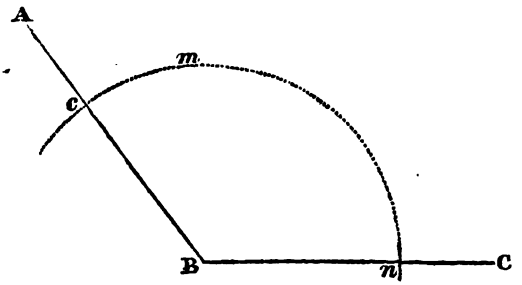
PROBLEM VI.

From a given point, B, *to make an angle of any number of degrees under* 180°, *suppose* 120°, *as* A B C.*

1. With 60° in the compasses, taken from the line of chords, and one point in B, make the arc *c n*.

2. Take 90° from the same line, which apply from *n* towards *m*, then take 30° from the same scale or line, which apply from *m* to *c*.

3. From B draw B C and B A, and they will form the angle A B C, as was required.



* Angles may be made more expeditiously by the semi-circle: thus, draw B C, and apply the flat side of the semicircle to it, making its centre coincide with the point B, then a mark made on the paper under the number of degrees required, reckoned from *n* towards *c*, on the circular part of the semi-circle, will point out the direction of the line B A, which, being drawn, will form the angle required.

But the sector is the most convenient instrument for drawing angles for any radius; thus, open the sector until the distance between C—C is equal to the intended radius, then take in the compasses the extent between C—C with which make an arc, as *n c*, one point being at B, the same extent will measure 60° on the arc *n c*, and will form an angle of 60°.

Example for an angle of 110.

From B, with the extent of 60°—60° taken from C—C in the sector, opened to the desired radius, make an arc, as *n c*, from *n* towards *c*; with the same opening of the compasses take off 60°, and from the same line C—C extend from 50°—50°, which apply on the arc, from where the 60° ended towards *c*, and it will be the arc of an angle of 110°, as was required.

Angles being given, to find the number of degrees they contain, may be measured by the preceding rules.

PROBLEM VII.

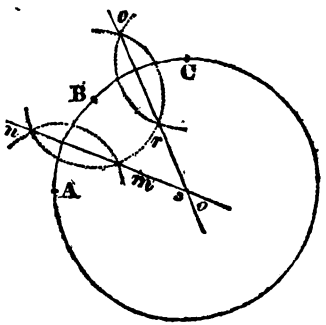
To pass a circle through three given points that do not lie in a straight line, as A B C.

1. With any convenient opening of the compasses, greater than half the distance between A B and B C, and one point in A, describe an arc, with the same opening and one point in B; cross the former arc in

n and *m*, with the point in B and C, describe similar arcs crossing each other in *o r*.

2. Through the sections *n m* and *o r* draw lines which will cross one another in *s*, the centre of the required circle.

3. Then, with the distance *s* A, *s* B, or *s* C, as a radius, describe a circle, and it will pass through the points A B C, as was required.



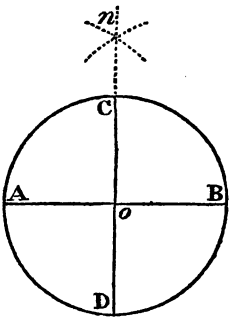
PROBLEM VIII.

To draw a diameter in a given circle, at right angles to another diameter, A B.

1. With any opening of the compasses, greater than half A B and one point in A, describe an arc with the same opening and one point in B, cut the former arc in *n*.

2. Through *n o* draw the line *n o* D, and C D will be the diameter required.

The section *n* may be more expeditiously found by applying the centre of the semi-circle to the centre *o*, making its flat side coincide with A B, then a mark at 90° will be the section *n*, a line through which and *o* will be the diameter required.



PROBLEM IX.

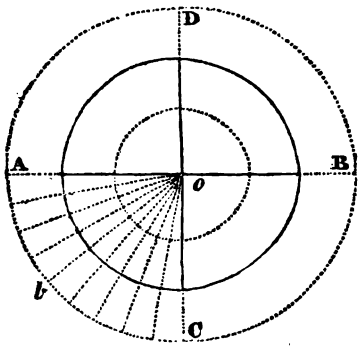
To divide a given circle, or any part thereof, into any number of equal parts, suppose A *b* C, *into nine equal parts.*

1. Divide the circle into quarters, by drawing diameters at right angles through it, as A B and D C.

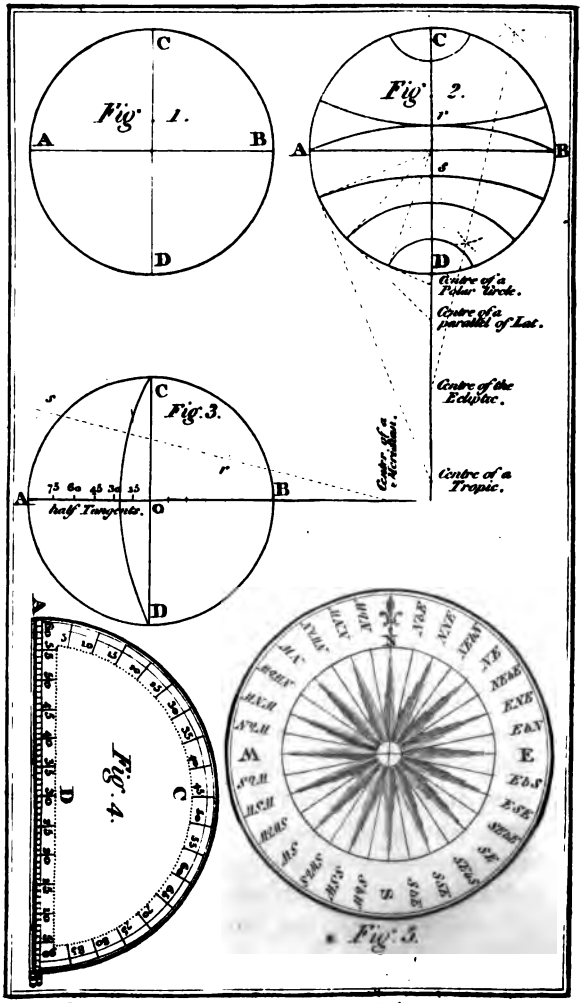
2. Divide the degrees in a quadrant, viz. 90°, by the number of parts required, in the annexed by 9, the

quotient shows the number of degrees equal to each division, which in this case is 10°.

3. Apply this distance, taken from the first part of the line of chords, from C to A, as often as it will admit, and it will divide the arc A *b* C into the number of parts required.



It is necessary to observe, that, except the given circle is drawn with the chord of 60°, the above rule is not applicable; in such cases, proceed as follows; from the centre of the given circle, as *o*, with the chord of 60° describe another circle, (either within, or without the given circle), to which produce the diameters, and divide as above; transfer the divisions found on the circle described by the chord of 60°, and they will divide the given circle into the parts required.



Engraved for Gray's Use of the Globes.

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1. *Note.* Circles, or any part thereof, may be more conveniently divided, by making the centre of the semi-circle coincide with the centre of the given circle, and its flat side with one end of the arc, to be divided; then mark off the degrees that each division contains, through which transfer lines from the centre, as above.

2. But the instrument best calculated for inscribing polygons of any number of sides into circles, or for dividing a circle, or an arc thereof, into any number of equal parts, is the sector, as it accommodates the divisions at once to any radius.

Rule. Open the sector, until C—C is equal to the radius of the given circle, then find the degrees answering to each division on the same lines, in the former case 10—10, take the extent between them in the compasses, which apply to the arc, or circle, to be divided as often as it will admit, and it will point out the divisions, as was required.

PROBLEM X.

*The stereographic projection of the sphere, or a map of the world, on the plane of the meridian.**

With the chord of 60° in the compasses, describe

* Although the sector can be commodiously applied in the stereographic projection, the plane scale will be found the simplest for beginners.

a circle, as A C B D, *(plate* 1. *fig.* 1.) to represent the meridian, or horizon, through which draw diameters at right angles, as A B and C D; then A B will represent the equator, and C and D will represent the poles, and also the zenith and nadir; and C D the equinoctial colure, and prime vertical circle; thus the circle will appear in quarters.

PROBLEM XI.

To find the centres of the parallels of latitude.

1. Divide the arc A C, or A D, by Problem IX. into as many equal parts as the proposed number of parallels of latitude to be projected in each hemisphere; the usual number is nine.

2. Draw lines from the centre of the circle *s*, *(plate* 1. *fig.* 2.) through each division on the divided arc of the horizon, and where these lines cut the horizon, raise perpendiculars towards the colure C D produced, which extend until they cut the colure produced, and their points of section will be the centres required.

3. For the tropics and polar circles: with $23\frac{1}{2}°$ in the compasses, from the line of chords, lay off that extent from the equator, both ways, for the tropics; and also from the poles for the polar circles, and find their centres as in the parallels of latitude.

4. For the ecliptic, bisect the distance *r* B, and through the sections extend a line, till it cut the colure produced; and the point where it crosses the colure, will be the centre of projection required.

N. B. The centres to any parallel, &c. found on one side, will be the radius of the corresponding parallel on the opposite side.

Another method for describing the tropics, parallels of latitude, &c. is by setting off the half tangents of their respective distances, taken from the scale, on the line marked S T, from the centre of the circle *s*, both ways on the colure, which will give the divisions through which the parallels, &c. are to pass. Their centres are found by setting off the tangents of their respective compliments, each way, from their points of section, in the colure, on the colure produced; or by setting off their co-secants from the centre *s* on the colure produced.

PROBLEM XII.

To find the centres of the meridians.

1. Find the points 15°, 30°, 45°, 60°, 75°, and 90°, (*plate* 1. *fig.* 3.) which will be hour-lines in the equator, by setting off their half tangents, taken from the line marked S T on the scale, from the centre of the circle *o*, both ways.

2. The centres are found by setting off the co-secants,* of the distances found in the equator, both ways, from their points of section with the equator, in the equator produced; or, with their co-tangents, set off both ways, from the centre of the circle on the equator produced.

1. *Note.* The centres of the meridians, or hour-lines, may be found, after the points are determined in the equator; by joining C or D with each division, as 15 C. 30 C, &c. bisect these lines, and lines carried through the sections, as *s r*, will cut the equator produced, in the centres required.

2. This method of finding the points through which the meridians are to pass, by setting off the half tangents from the plane scale, is only applicable when the radius of the sphere is taken from the line of chords. To find the points of section for any given radius, open the sector until the distance between C—C is equal to the given radius, then take the half tangents of their distance from the lines on the sector marked T—T, which apply as before, and find their

* It is necessary to observe, that the line of secants on the plane scale begins, where the line of sines ends, but is reckoned from the brass nob at the left of the line of sines: thus, 50 secants are equal to the extent from the brass nob, at the left of the line of sines, to the 50 on the right of the 90, on the line of sines, and equal to nearly 57 on the adjoining line of tangents.

centres as in the preceding note; that is, by joining the pole and each division, &c.

Note. The lines on the sector marked T—T are whole tangents, therefore, when applied, each degree is to be reckoned for two; *t*—*t*, on the sector, are half tangents; but as these lines generally run very obscure towards the centre, the former lines will be found most convenient for use.

PROBLEM XIII.

To project a figure, whereby the breadth of a degree, in any latitude, can be found in geographical miles.

1. With any convenient opening of the compasses, and one point in D, describe the semicircle A C B, *(plate* 1. *fig.* 4.*)* which divide into 90 equal parts by Problem IX.

2. Join A B, to represent a degree on the equator, and divide it into 60 equal parts, to represent the miles in a degree.

The line A B can be divided into twelve equal parts by Prob. V. and then each division subdivided into 5 equal parts. The circular part of this figure may be more expeditiously divided than by Prob. IX. by placing the flat edge of the semicircle on the line A B, making its centre coincide with D, then dots made at every two degrees, and lines drawn from the

centre D, through these dots, will divide the circle into 90 equal parts, as was required.

APPLICATION. The extent from 90°, at B, to the proposed parallel of latitude on the circular part, will reach from B, to the number of miles on the line A B, that are in a degree in the proposed parallel of latitude.

1st Example, for lat. 51° 30′.

The extent from 93°, at B, to 51° 30′ on A C B, will reach from B towards A to $37\frac{3}{4}$ miles, nearly the breadth of a degree in the parallel of London.

2d Example, for lat. 60°.

The extent from 90°, at B, to 60° on A C B, will reach from B to D, being 30 miles, the breadth of a degree in the latitude required.

5. THE MARINER'S COMPASS, *plate* 1, *fig.* 5.

Is an instrument used by navigators at sea, to direct their course, and to point out their track in the pathless ocean; by which means they can determine their way in a dark night the same as at noon-day.

This instrument is used in geography, to place the globes north and south, and, in idea, to show the cardinal points of the maps; and to determine which

way one place lies (or bears) from another on the maps; or by an angle of position on the globes, (see note, Prob. xlv.) it is also used by travellers in hot and desert countries where there is no road, or track, and in which they are, on account of the heat, obliged to travel in the night time; as in the deserts of Arabia and Africa.

The pocket compass would be useful to those passing through large forests on foot, where there is no regular path; as it would enable them to proceed in one direction, and prevent their being bewildered, by winding about in all directions. At the north and south poles, the compass loses its use, because at the former place every thing bears to the south, and at the latter, every object lies to the north.

At what time the mariner's compass was invented is not well ascertained; it is however generally ascribed to Flavio de Melsi, or Gio, a Neapolitan, who discovered, or at least improved it, about A. D. 1302; others say that Marcus Paulus, a Venetian, brought the invention home from China, in 1260; and that it was known by their emperor Chiningus 1120 years before Christ.

This opinion is strengthened by the Venetians using the compass at first, in the manner that the Chinese still do; that is, they let it float on a little piece of cork, instead of suspending it on a pivot, as it is now

used. The Chinese divide their compass into twenty points instead of thirty-two.

The French lay claim to it as their invention, from the *Fleur-de-lis* wherewith all nations distinguish the north point of the card; and this also points out the north of all maps, charts, plans, &c. wherever it is placed.

D. Wallis, and others, with great propriety, ascribe it to be of English invention, from its name *compass*, which word is used in various descriptions in England, and is the name whereby it is denominated in most nations; and this discovery is ascribed to the learned philosopher, Roger Bacon, of Somersetshire: he died about 1284.

The variation of the compass is the angle that the needle makes with the true north point; this variation is continually changing, being different in the same year at most places on the earth, at some places to the east, and at others westerly, scarcely any two of them agreeing at the same time; it also hasa regular diurnal and annual variation.

The variation of the compass is said to have been discovered by Columbus in 1492, and was first observed at London in 1576, to be 11° 15′ easterly; and in 1622, it was 6° east, still decreasing, and approaching towards the true pole, with which it coincided in 1662; since that time the variation has increased

westerly, at about eleven minutes every year, and in 1806 it was found by Mr. Gilpin, at the apartments of the Royal Society, to be 24° 8′ W. increasing westerly at a small rate; and in 1814, 24° 16′ W.

This curious and extraordinary phenomenon in nature is not yet accounted for; and its uncommon varieties would require a description far beyond the limits of our plan; we must therefore refer the curious reader to Mr. Gilpin's Treatise, where it is particularly explained.

The magnet, which produces this phenomenon, and gives polarity to the needle, is by some called *Lapis Heracleus*, from Heraclea, a port of Lydia, in Asia Minor, where it is said to have been first found. Others take the name from Magnus, a shepherd, who first discovered it with the iron of his crook, on Mount Ida. It is commonly known by the name of *load-stone*, a sort of mineral stone resembling iron ore, or rusty iron, and is found in various countries; the best sort is reported to come from China and Bengal.

6. To project the Mariner's Compass.

Plate 1. *fig.* 5.

I. By Geometry.

1. With any convenient opening of the compasses draw the circle N. E.—S. W.

2. Cross the circle with diameters, at right angles, (by Prob. viii.) as N. S. & E. W. which will represent the four cardinal points; and the circle will be divided into four equal parts.

3. Bisect the arcs N. E.—E. S.—S. W. & W. N. (by Prob. i.) and from the centre draw lines through each of these sections, and these will show the S. W. —S. E.—N. W. & N. E. points of the compass; and the circle will then be divided in 8 equal parts.

4. Bisect each of these divisions, and lines drawn as before will divide the circle into 16 equal parts; and each of these arcs being again bisected, will produce 32 divisions, which are equal to the number of points required.

5. Attach to each point its proper name, and the compass will be finished; the ornamental part being left to the taste of the drawer.

II. *By the Line of Chords.*

1. With 60° in the compasses taken from the line of chords, as a radius, describe a circle.

2. Take from the same scale of chords, 11° 15′ in the compasses, and beginning at the north point, apply it as often as it can, and it will divide the circle into 32 equal parts, as before.

III. *By the Semicircle.*

1. Draw any circle at pleasure, through which pass a diameter.

2. Apply the semicircle, by making its flat edge coincide with the diameter of the circle, and its centre with the centre of the circle.

3. With a pencil make dots round the circular edge of the semicircle at every 11 15′, which will divide half the circle into 16 equal parts; then a ruler, by these dots and the centre of the circle, will point out the divisions on the opposite side; or the semicircle may be transferred to it, and applied as before.

The points may also be found by the sector, as in the note at Prob. IX.

7. *To find how often any of the less orbs in the solar system, are contained in the greater; as the moon in the earth, the earth or planets in the sun, &c.*

Rule. Cube the diameters of the given orbs, and divide the greater cube by the less; and the quotient will show the number of times that the less orb is contained in the greater, and consequently their comparative magnitudes.

Example 1. The diameter of the earth is 7940

miles, and that of the sun 890,000 miles: required how often the earth is contained in the sun?

The sun's diameter cubed is equal to 704,969,000,000,000,000 miles, and the cube of the earth's diameter is 500,566,184,000; and the former number divided by the latter, produces 1,408,343, being the number of times that the earth is contained in the sun.

Example 2. The diameter of the earth being given 7940 miles, and that of the moon 2180 miles; required how often the moon is contained in the earth? Answer, 48 times.

Note. To cube any number is to multiply it by itself, and that product again by the number, the last product is the cube, as the cube of 4 is found thus; $4\times4=16\times4=64$, equal to the cube of four.

8. The diameter of a circle to its circumference in whole numbers, is, as 7 is to 22, that is, if the diameter is 7 feet, yards, &c. the circumference will be 22 feet, yards, &c. This proportion was determined by *Archimedes*, of Syracuse, two thousand years ago. Other proportions are, as 113 is to 335; or, as 1 is to 3·14159, the last being the nearest; but cannot be applied without some knowledge of decimal arithmetic. The exact proportion that the diameter of a circle bears to its circumference, has not yet been found; it has excited the research of the world for many years; the Emperor Charles V. offered a reward of one hun-

dred thousand crowns to the person who should solve this celebrated problem; and the States of Holland have proposed a reward for the same purpose.

9. *To find at what rate the inhabitants of the earth are carried in a year, day, hour, minute, and second, by the annual motion of the earth.*

Rule. Multiply the earth's distance from the sun by 2, which gives the diameter of the earth's orbit; multiply that by 22, and divide the product by 7; the quotient is the whole extent of the orbit of the earth, and consequently the number of miles we are carried in a year: divide them by 365, the quotient will show the number of miles that we daily pass through; this divided by 24, shows the hourly motion; and that again by 60, produces our motion per minute, which being divided by 60, gives the rate we are carried at per second; or in the time that a pendulum clock beats.

Example. The distance of the earth from the sun, at a mean rate, is given 95,000,000 miles: required at what rate we are carried in a year, day, hour, minute, and second, by the annual motion of the earth?

According to the first rule, which is the most convenient for general use, we find that the vast space passed through in a year, by the earth, is 597,142,857 miles,

in a day 1,636,007 miles, in an hour 68,166 miles, in a minute 1136 miles, and in a second $18\frac{6}{10}$ miles. The uniformity of this rapid motion prevents our feeling or suffering any inconveniency from it.

10. *To find at what rate the inhabitants on any part of the earth are carried, by its diurnal motion.*

NOTE. The points of the earth at the poles, have no diurnal motion, except that of being turned round in the same place every twenty-four hours.

RULE. Multiply 360, (the circumference of the earth), by the number of miles contained in a degree of the parallel of latitude where the proposed place is situated, (a table of which is given in Chap. IV. Prob. X. for geographical and English miles,) and the product will be the daily motion; divide that product by 24, and the quotient will show the hourly motion; which, if divided by 60, will give the motion per minute.

Example 1. Required at what rate per day, and per hour, the inhabitants at the equator are carried by the diurnal motion of the earth in English miles?

Answer, 25,020 miles per day, and 1042 per hour.

2. At what rate are the inhabitants of London carried per hour, and per minute, by the diurnal

motion of the earth in English miles? the breadth of a degree in that parallel, being about 43½ miles.

Answer, 648 miles per hour, and 10$\frac{8}{60}$ per minute.

CHAP. II.

The rise and progress of geography; definitions of the lines used on the globes, the signs of the zodiac, positions of the sphere, &c.

1. The Rise and Progress of Geography.

THE origin of geography, on which the use of the terrestrial globe is founded, is not of a late date, nor is it likely that a system was formed from the invention of one man: it appears, however, to have been brought to such perfection in the time of Anaximander, the scholar of Thales, a native of Greece, who flourished six hundred years before Christ, that he was able to bring it into regular form, by inventing maps, globes, and the signs of the zodiac.*

* Maps and sea-charts were first brought to England by Bartholomew Columbus, in 1489; brother to the celebrated Christopher Columbus, who discovered America.

Pliny informs us, that Alexander the Great carried geographers with him, to delineate his expeditions in Asia. It was likewise customary among the Romans to delineate their conquests on tables, which were exhibited to the people in their triumphs.

The moderns have, however, added much to the science of geography, by exploring extensive regions unknown to the ancients; of which America, New Holland, and the numberless islands in the Southern Ocean, may be considered as the principal; and have quite exploded the idea of a continent, to any considerable extent, existing towards the south pole.*

The first person that sailed round the earth was Magellan, a native of Portugal, in the service of Spain, who completed his voyage in 1520. The same was performed by Sir Francis Drake, Lord Anson, Captain Cook, &c.

These circumnavigators, not only added information to the system of geography, but likewise a proof of the globular shape of the earth.

That the earth is round, like a ball, is proved by ships having sailed round it; by its shadow, in eclipses of the moon, always being bounded by a circular line; by our seeing the masts of a ship whilst the hull is

* Captain Cook sailed, on the 30th of January, 1774, to the lat. of 71° 10′ S. being then surrounded with islands of ice.

hid by the convexity of the water: as the hills take off no more from the roundness of the earth, in comparison, than grains of dust do from the roundness of a common globe.

The exact shape of the earth was a contested point, of some length, among mathematicians and philosophers; the means that led to its determination were, however, accidental. In the year 1672, Mr. Richer being sent from Paris to Cayenne, in S. America, lat. 4° 56′ N. found that his pendulum clock, which was regulated at Paris to mean time, lost every day nearly three minutes, which is more than could have been produced by the expansion of the pendulum by the hot climate.

This discovery being reported by Mr. Richer, on his return to France, engaged the attention of the greatest philosophers and mathematicians of Europe: it is, however, to the sagacity of Sir Isaac Newton that the world is indebted for the solution of this complex problem, who, from the idea afforded by the observations of Richer, formed an hypothesis, whereby he determined that the earth was in the shape of an oblate spheroid; that is, flattened a little towards the poles, and that its equatorial diameter was nearly 37 miles longer than its polar.*

* The earth's equatorial diameter is equal to 41,926,356 feet, or 7940.598 miles; and the polar diameter is equal to 41,731,272

A few years prior to this, viz. in 1635, Mr. Richard Norwood, in order to determine the length of a degree on the earth, measured the distance between London and York, by the method of traverse sailing, measuring likewise the distance of their zeniths; the result of which was, that a degree of a great circle is equal to 69½ miles (nearly) English statute measure. Hence these two great problems, relating to the shape and measure of the earth,* were determined, and established on a footing not likely to be overturned, although some attempts have been made to call it in question.†

feet, or 7903.65 miles; so that the equatorial diameter is 195084 feet, or 36.948 English miles longer than the axis: and its circumference on the equator 24946.286 miles English.

* The seas and unknown parts of the earth, according to Mr. Turner, contain about 160,522,026 square miles on their surface; Europe 4,456,065; Asia 10,768,823; Africa 9,654,807; America 14,110,874 miles; total 199,512,595 square miles on the whole surface of the globe. The number of its inhabitants, exclusive of New Holland and the islands in the Southern Ocean, are estimated at 884,600,000, viz. Europe 124,600,000, Asia 450,000,000, Africa 150,000,000, and America 160,000,000.

† By Buffon, Condamine, Maupertuis, and Boscovick. Goldsmith's Experimental Philosophy, Vol. 1. p. 123.

Definition of the Circles, or Lines, on the Terrestrial Globe.

An artificial globe is a round body, having every part of its surface equally distant from a point within it, called its centre.

The terrestrial globe has an Atlas,* or a complete set of maps, laid down on its surface, in which the land and water are placed in their natural position as on the earth.†

* A set of maps is called an Atlas, in respect to a king of that name, in Mauritania, in Africa, now the kingdom of Morocco, &c. famed for his knowledge in astronomy. There is a range of mountains, running from Egypt to the Atlantic Ocean, that bears his name; also the Atlantic is named from the same origin.

† *Explanations of Contractions and Characters used in this Treatise.*

Arcs of Circles

° *stands for* degrees
' miles or minutes

Time.

deg. degrees
min. minutes
sec. seconds

lat. latitude
lon. longitude
dec. declination
alt. altitude
r. ascen. ... right ascension
quad. quadrant

dist. *stands for* distance
merid. meridian
N. north
S. south
E. east
W. west
A. M. before noon
P. M. afternoon
\+ added
— subtracted
× multiplied
= equal to
diff. difference

Annexed to the terrestrial globe are the following:

1. The brass meridian, (a great circle,* dividing the earth into two equal parts, called the eastern and western hemispheres,) which is divided into four equal parts, each containing 90°; two divisions begin at the poles, and two at the equator, marked 10, 20, 30, &c. on the graduated edge.†

2. The poles, two in number, the one called the north pole, the other the south pole; these lie at the north and south extremities of the earth, being likewise the ends of the axis on which the artificial globe turns.

3. The axis of the earth is an imaginary right line passing through its centre, upon which it is supposed to turn, and is that line on which the artificial globe turns.

4. The horizon is the broad frame in which the globe is supported, the surface of which represents the true horizon,‡ and divides the globe into two equal parts, called the upper and lower hemispheres.

* Great circles divide the earth into two equal parts, called hemispheres; lesser circles into unequal parts, called segments.

† The graduated edge of the meridian and quadrant of altitude is the side, where the degrees and their subdivisions are placed.

‡ The visible or sensible horizon, being that imaginary circle which we see in a clear day, where the earth and the sky seem to meet.

The lines marked on the horizon are, first, The points of the compass, or thumb lines, being thirty-two in number, each equal to 11° 15′ and are marked thus: N. N. by E.—NNE.—NE. by N.—NE., &c. Second, The twelve signs of the zodiac, with the corresponding month and day, as in the following table:

NORTHERN SIGNS.

Spring.

♈ Aries, the Ram,	from March 20th	to April 20th
♉ Taurus, the Bull,	 April 20th	... May 21st
♊ Gemini, the twins,	 May 21st	... June 21st

Summer.

♋ Cancer, the Crab,	from June 21st	to July 23d
♌ Leo, the Lion,	 July 23d	... August 23d
♍ Virgo, the Maid,	 Aug. 23d	... Sept. 23d

SOUTHERN SIGNS.

Autumn.

♎ Libra, the Balance,	from Sept. 23d	to Oct. 23d
♏ Scorpio, the Scorpion,	... Oct. 23d	... Nov. 22d
♐ Sagittarius, the Archer,	... Nov. 22d	... Dec. 21st

Winter.

♑ Capricornus, the Goat,	from Dec. 21st	to Jan. 20th
♒ Aquarius, the Water-bearer,	Jan. 20th	... Feb. 19th
♓ Pisces, the Fishes,	 Feb. 19th	...March 20th

Each sign contains 30°, and is subdivided into single degrees, and commonly marked on the third line, or circle; the fourth circle contains the twelve calendar months; the fifth exhibits the days of the month, answering to, and opposite to, the degree of each sign that the sun is in on those days.

Note, That some globes have the calendar answering to the old style, or Julian account; also circles showing amplitude and azimuth: but the former being quite out of use, and the latter more particularly attached to the celestial globe, will be introduced there; it seems unnecessary here to describe them farther.

The preceding table will point out which of the circles, on the old globes, shows the day of the month for the new style, it being regulated accordingly; that is, the 20th of March answers to the first of Aries; therefore the circle that shows the same on the globe, points it out to represent the new style.

5. The hour circle, placed at the extremity of the axis, is drawn on the ball of some globes; on others, it is a flat ring of brass, screwed on the meridian, at the north pole, having marked on it twice twelve, or twenty-four hours, answering to a natural day, and to the time that the earth performs its daily motion on its axis. The upper XII represents noon, the lower XII represents midnight; the hours on the eastern side show the time before noon, that is, from midnight to noon; and those on the western side, the hours from noon to

midnight. The index, or hour-hand, attached to the circle, is placed on the axis, and turns round with the globe, or may be set to any hour.

6. The quadrant of altitude* is a thin pliant slip of brass, commonly graduated to 108° of the same size with those on the equator, and is marked 10, 20, 30, &c.

7. Meridians are great circles, cutting the equator at right angles, and extend from pole to pole, quite round the globe, and are generally placed 15° asunder, hence they represent hour-lines.

8. The equator† is a great circle, equidistant from the poles, dividing the earth into two equal parts, called the northern and southern hemispheres.

9. The ecliptic‡ is a great circle, crossing the equator at Aries and Libra, the equinoctial signs, making an angle of 23½°,§ and comes in contact with the

* The quadrant of altitude ought to be graduated to 108°, which it is on some globes, in order to determine the beginning and ending of twilight.

† The equator is so called, because it is equally distant from the poles, and because, when the sun is in it, the days are equal all over the earth, except at the poles.

‡ The ecliptic, so called because eclipses happen in or near to it.

§ The obliquity of the ecliptic is now 23° 28′, but in practice on the globes it is commonly made 23½°.

tropics at the first degree of Cancer and Capricorn, the solsticial signs, it represents the yearly path of the earth round the sun, and on it are placed the characters of the signs of the zodiac.

10. The zodiac, which signifies a zone of animals, is a broad circle, not marked on the terrestrial globe, sixteen degrees in breadth, in which the twelve signs are placed; the ecliptic passes through the middle of it, and in it the motion of the sun, moon, earth, and planets, are performed as they appear from the earth; the sun only being always in the middle of it; that is, in the ecliptic.

11. The tropics denote a return, two in number, (Cancer the northern, and Capricorn the southern,) and are lesser circles of the earth, each being $23\frac{1}{2}^{\circ}$ distant from the equator.

12. The polar circles, two in number; arctic, or northern, from Arcas, or the bear; antarctic, or southern, are lesser circles, each being $23\frac{1}{2}^{\circ}$ from its pole.

13. Parallels of latitude are lesser circles, and are all the circles which go round the globe, from left to right, except those specified above.

Latitude is the distance of places from the equator, north or south, extending at the poles to 90°, and is reckoned on the brass meridian. Those who live on the equator have no latitude.

14. Longitude is the distance of any place from

the first meridian,* extending to 180° E. or W. and is reckoned on the equator. The lines which represent longitude on the globe, are the meridians, or great circles, which pass from one pole to the other. Those who live under the first meridian have no longitude.

15. Zones, five in number, viz. two temperate, two frigid, and one torrid. The temperate zones lie between the tropics and the polar circles, each being 43° broad, named from the air being in them more temperate than in the other zones. The frigid zones are situated between the polar circles and their poles, each 23½° broad, so named from these regions being frozen great part of the year. The torrid zone lies between the tropics, being 47° in breadth, and is named from its extreme heat.

16. Positions of the globe are three: right, oblique, and parallel.

First, A right globe, or sphere, hath two properties, viz. that the equator makes a right angle with the

* On some globes, the first meridian is fixed at the island of Ferro, 17° 45′ west of London; others at Teneriff, 16° 25′ west. The determining of a first meridian is however quite arbitrary; but the general practice is, to consider the first meridian to pass over the capital of its respective country: modern maps and globes, of English projection, consider London the first meridian, or, more accurately, Greenwich, which is five miles east of it. The Dutch, formerly Batavia, now Amsterdam; the French, Paris, &c.

horizon, in which are the poles, and passes through the zenith and nadir ;* the inhabitants that have this position of the earth, are those that live on the equator, and have their days and nights always equal.

Second, An oblique globe is that position of the earth where the equator makes an acute angle with the horizon, one of the poles is elevated above the horizon, and the other depressed beneath it: those who have the earth in this position live between the equator and poles; their days and nights are unequal.

Third, A parallel globe is when the horizon coincides with the equator, and the poles are in the zenith and nadir; this position is peculiar to the polar regions, where there is only one day and one night in the year.

17. Antœci, are those who live on two parts of the earth, situated on the same meridian, but opposite latitudes; the summer of the one is the time of winter with the other, their hours of the day are the same. Those who live on the equator have no antœci.

18. Periœci, are those who live on the same parallel of latitude, but opposite longitudes; the noon time at the one is midnight with the other; the length of the days and nights, and seasons of the year, are the same. The inhabitants at the poles have no periœci.

* Zenith is that point of the heavens which is directly over our heads; and the nadir is the point diametrically opposite, or under our feet.

¶

19. Antipodes, are those who live on opposite meridians and opposite parallels of latitude; their seasons are opposite; when it is summer with the one it is winter with the other; when it is noon with the one it is midnight with the other; and the feet of the one are opposite to the feet of the other.

20. Declination* is the distance of the sun's place from the equator, north or south, and extends to the tropics, being $23\frac{1}{2}^{\circ}$, and is measured on the brass meridian.

21. The sliding hour circle on the modern improved globes, by Bardin, differs from the common hour circle, it having on the outer circle, the points of the compass; and likewise it is fitted into a groove on the back of the brass meridian, in which it slides, and therefore the S. pole can be elevated, and the discoveries there laid down, exhibited with as much ease as at the N. pole.

22. The analemma is a small slip of paper pasted on the globe, extending from the tropic of Cancer to the tropic of Capricorn. It contains the calendar months and days, in two parts; the first part begins at the winter solstice, or 21st of December, and proceeds to

* Declination and latitude agree in this respect, that they are the distance of the sun's place, or a place on the earth, from the equator; but they are different, inasmuch as latitude extends to the poles, whereas declination extends only to the tropics.

the summer solstice, or 21st of June; the second part, from the 21st of June to the 21st of December.

The months and days correspond with the sun's declination, north or south.

CHAP. III.

Contains fifty Problems on the Terrestrial Globe, including the Use of the Analemma and Sliding Hour Circle; with a Table showing the Breadth of a Degree of Longitude in any Latitude, a Table of the Equation of Time, and a Table of Climates, &c.*

PROBLEM I.

To rectify the globe for any place whose latitude is given.

Elevate the pole that bears the same name with the latitude of the given place, as many degrees above the horizon as are equal to the given latitude, suppose London, in lat. 51° 30′ N. First, the north pole must

* It appears necessary to observe here, that the problems on the terrestrial globe are practical geography; hence the absolute necessity of being well acquainted with that subject in the common way, before an attempt is made to apply it on the globe.

be raised until 51° 30′ on the brass meridian coincide with the upper surface of the horizon, then London must be brought to the meridian, and the quadrant of altitude screwed on it, in the zenith, that is over the given place; place the globe on an horizontal plane, due south and north, which may be done nearly by estimation, or more accurately by the mariner's compass fixed to the horizon, or on the pedestal of the globe, care being taken to correct for the variation of the needle, which has already been observed at p. 29 to have been 24° 16′ W. at London in 1814, therefore turn the globe to the right, or left, till the needle stands over the above degree. Thus the globe will be rectified for London, and correspond, in every respect, with the real position of the earth for the place given.*

* The latitudes and longitudes used in this treatise are, where practicable, taken from the eighth edition of Moore's Navigation; but the situation of the interior parts of the most of Africa, Asia, and America, are laid down so differently by geographers, as to raise much difficulty in determining, and cannot be justly depended on. The problems, where calculation is not convenient, are solved from the improved globes of eighteen inches and twelve inches in diameter, lately engraved, and sold under the title of "Bardin's new British Globes." On the terrestrial eighteen-inch globe are included the late discoveries of Captain Cook, Vancouver, Perouse, Mungo Park, &c. to the present time, and on the corresponding celestial globe are depicted the exact positions of more than 6000 stars, clusters, nebulæ, &c. the whole forming the completest globes of any hitherto published.

Given Cape Horn in 55° 58′ S. lat. to rectify the globe for.

Raise the S. pole until 55° 58′ coincide with the upper surface of the horizon, bring the Cape to the meridian, and proceed with the rest as in the preceding example.

PROBLEM II.

A place being given, to find its latitude and longitude.

Bring the place to the graduated side of the brass meridian; and the number that stands over it is the latitude, and the degree cut by the meridian on the equator is the longitude.

Given London; required its latitude and longitude? Answer, lat. 51° 30′ N. lon. 0.

Given Constantinople; required the latitude and longitude? Answer, lat. 41° 1′ N. lon. 28° 57′ E.

Required the latitude and longitude of the Cape of Good Hope? Answer, lat. 34° 29′ S. lon. 18° 29′ E.

PROBLEM III.

The latitude and longitude of a place being given, to find the place on the globe.

Turn the globe until the given longitude comes to

the graduated edge of the brass meridian, then under the given latitude, on the meridian, will be the place required.

A place in 41° 1′ N. lat. and lon. 28° 57′ E.; required the place? Answer, Constantinople, the capital of Turkey, in Europe.

Given a place in 34° 29′ S. lat. and 18° 29′ E. lon.; required the place? Answer, the Cape of Good Hope.

Required the name of the place that has 18° 4′ N. lat. and 76° 40′ W. lon.? Answer, Kingston, the capital of Jamaica.

PROBLEM IV.

A place being given, London for example, to find all those places that have the same latitude and longitude.

Bring London to the brass meridian, then all those places that lie under the meridian have the same longitude, viz. 0; mark the latitude of the place on the meridian, turn the globe quite round, and all those places that pass under the mark have the same latitude, viz. 51° 30′ N.*

* The globe may be marked, at any particular part of a problem, by a pencil, a bit of chalk, or small patch of wetted paper.

PROBLEM V.

To find the Antœci of any place given.

Bring the place to the meridian, note its latitude, find the same latitude, without moving the globe; on the other side of the equator, and under it is the antœci required.

Given London; required its antœci? Answer, under 51° 30′ S. lat. in the Southern Ocean.

Given the Island of Malta, in the Mediterranean Sea; required its antœci? Answer, under 35° 53′ S. lat. and 14° 32′ E. lon. near the Cape of Good Hope.

Required the antœci of St. Helena, in lat. 16° 4′ S. and lon. 5° 54′ W.? Answer, at 16° 4′ N. lat. and lon. 5° 54′ W.

PROBLEM VI.

To find the Periœci of any place given.

Bring the place to the meridian, mark the degree of latitude over it, set the index to the upper XII, turn the globe until the index points to the lower XII; and the place under the mark is the periœci required.

Given London; required its periœci? Answer, under 51° 30′ N. lat. and 180° E. or W. lon. in the sea of Kamschatka.

Required the periœci of Petersburgh, the capital of Russia? Answer, under 59° 56′ N. lat. and 149° 35′ W. lon. near Cook's River, N. W. coast of America.

At what latitude and longitude is the periœci of Botany Bay, in New South Wales? Answer, under 33° S. lat. and 28° W. lon. in the S. Atlantic.

PROBLEM VII.

To find the Antipodes of any place.

Bring the given place to the meridian, note its latitude, set the index to the upper XII, turn the globe till the index points to the lower XII; and the place under the same degree of latitude on the opposite side of the equator, to that which the given place lies, is the antipodes required.

Given London; required its antipodes? Answer, under 51° 30′ S. lat. and 180° E. lon. in the Southern Ocean.

Required the antipodes of Vienna, the capital of Germany? Answer, under 48° 13′ S. lat. and 163° 32′ W. lon. in the Southern Ocean.

What part of the earth is antipodes to Cape Horn, in lat. 55° 58′ S. lon. 67° 20′ W.? Answer, under 55° 58′ N. lat. and 112° 40′ E. lon. in Siberia, near the source of the Lena.

Another method whereby the Antœci, Periœci, and Antipodes, may be found, by one position of the globe.

Place the poles in the horizon, and bring the given place to it, note the degree of amplitude, azimuth, or the point of the compass that coincides with it; then the same point or degree found on the other side of the equator, and on the same side of the horizon, with the place given, will point out the antœci; and the same point, &c. on the parallel of lat. where the given place is situated, and on the opposite horizon will show the periœci; also the same degree, &c. with the given place, found on the opposite side of the horizon, and in the opposite hemisphere, will point out the antipodes.

Given the Cape of Good Hope; required its antœci, periœci, and antipodes?

The poles being placed in the horizon, and the Cape of Good Hope brought to the eastern side of it, the Cape is found to coincide with 35° of amplitude, at 35° on the same side of the horizon, and in the opposite hemisphere, is a point in the Mediterranean sea, E. of Sicily, the antœci required; at 35° amplitude on the same parallel of lat. and in the opposite horizon, is a point in the Pacific Ocean, E. of New Zealand, which answers to the periœci of the Cape; and at 35° amplitude on the opposite horizon, and opposite he-

misphere, is a point in the Pacific, North of the Sandwich isles, the antipodes required.

Note. This problem cannot be solved by the above method, on the globes that have the hour circle fixed to the brass meridian.

PROBLEM VIII.

To find the difference of latitude between two given places.*

Bring one of the places to the meridian, mark the degree over it, bring the other place to the meridian, and reckon the number of degrees between it and the mark, which will give the difference required.

Given London and the N. point of the island of Madagascar; required their difference of latitude? Answer, 63° 45′.

Required the difference of latitude between Cape St. Vincent's, in Portugal, and Grand Cairo, in Egypt? Answer, 6° 59′.

* If the places lie both on the same side of the equator, the difference of latitude may be found by subtracting one of the latitudes from the other; if on both sides of the equator, add them for the difference of latitude; and if one of the places be on the equator, then the latitude of the other places is the difference of latitude required.

What is the difference of latitude between Cape North, the northern extremity of Europe, and Cape Horn, at the southern extremity of America? Answer, 127° 8′.

PROBLEM IX.

To find the difference of longitude between two given places.*

Bring one of the places to the meridian, mark its longitude on the equator, bring the other place to the meridian; the number of degrees between which and the mark is the difference of longitude required.

Given London, and Pekin in China; required their difference of longitude? Answer, 116° 36′.

Required the difference of longitude between Bos-

* The difference of longitude may be found by the preceding note; that is, if the places lie on the same side of the first meridian, subtract their longitudes, and the remainder will be the difference of longitude; but, if on contrary sides of the meridian, add them, and if their sum do not exceed 180°, it is the difference required; but if it exceeds 180°, which is the greatest longitude, subtract it from 360°, and the remainder will be the difference of longitude required; and if one of the places is on the first meridian, then the longitude of the other place is the difference of longitude.

ton in North America, and Cape Verd, in Africa? Answer, 53° 4′.

What is the difference of longitude between Bergen, in Norway, and Lima, in Peru, S. America? Answer, 82° 50′.

PROBLEM X.

To measure the distance between two given places that have the same longitude, or that lie due north and south of each other.

Bring the places to the meridian, count the number of degrees between them, which multiply by 60 for geographical miles, or 69½ for their distance in English miles.

Given a place in 60° 10′ N. and another in 15° 20′ N. lon. 20° E. or W.; required the distance in geographical miles? Answer, 2690 miles.

Required the distance between two places of the same longitude, the one lying in 40° 15′ N. and the other in 54° 45′ S. in English miles? Answer, 6602½ miles.

*A Table showing the length of a degree of longitude, in any latitude, in geographical miles, and English statute measure, and hundred parts of a mile.**

Deg. Lat.	Geog. miles.	English miles.	Deg. Lat.	Geog. miles.	English miles.	Deg. Lat.	Geog. miles.	English miles.
0	60 —	69.5	30	51.96	60.19	60	30 —	34.75
1	59.99	69.49	31	51.43	59.57	61	29.09	33.69
2	59.96	69.46	32	50.88	58.94	62	28.17	32.63
3	59.92	69.40	33	50.32	58.29	63	27.24	31.55
4	59.85	69.33	34	49.74	57.62	64	26.30	30.47
5	59.77	69.24	35	49.15	56.9	65	25.36	29.37
6	59.67	69.12	36	48.54	56.23	66	24.40	28.27
7	59.55	68.98	37	47.92	55.5	67	23.45	27.15
8	59.42	68.82	38	47.28	54.77	68	22.48	26.30
9	59.26	68.64	39	46.63	54.01	69	21.51	24.91
10	59.09	68.44	40	45.96	53.24	70	20.52	23.77
11	58.89	68.22	41	45.28	52.45	71	19.53	22.63
12	58.69	67.98	42	44.59	51.65	72	18.54	21.48
13	58.46	67.72	43	43.88	50.83	73	17.54	20.32
14	58.22	67.43	44	43.16	49.99	74	16.54	19.16
15	57.95	67.13	45	42.43	49.14	75	15.53	17.99
16	57.67	66.81	46	41.68	48.28	76	14.52	16.81
17	57.38	66.46	47	40.92	47.4	77	13.50	15.63
18	57.06	66.10	48	40.15	46.5	78	12.48	14.45
19	56.73	65.71	49	39.36	45.6	79	11.45	13.26
20	56.38	65.31	50	38.57	44.67	80	10.42	12.07
21	56.01	64 88	51	37.76	43.74	81	9.38	10.86
22	55.63	64.44	52	36.94	42.79	82	8.35	9.67
23	55.23	63.98	53	36.11	41.83	83	7.31	8.47
24	54.81	63.49	54	35.27	40.85	84	6.27	7.26
25	54.38	62.99	55	34.41	39.86	85	5.22	6.05
26	53.93	62.47	56	33.55	38.86	86	4.18	4.84
27	53.46	61.92	57	32.68	37.85	87	3.14	3.63
28	52.97	61.36	58	31.79	36.83	88	2.09	2.42
29	52.48	60.79	59	30.90	35.8	89	1.05	1.21

* Sixty-nine and a half miles English are reckoned to a degree in this table.

Example. Required the length of a degree in geographical

PROBLEM XI.

*To measure the distance of two given places that lie E. and W. of each other, or on the same parallel of latitude.**

Bring one of the places to the meridian, mark its longitude, turn the globe till the other place comes to the meridian, then the number of degrees between the mark and the meridian, multiplied by the miles in

and English miles, in 51°? In the column marked deg. lat. find 51, against which, on the right, in the column marked Geog. miles, is 37.76 geog. miles, and in the next column, under English miles, is 43.74, being the lengths required. The calculations in this table extend only to degrees; to find the same for any odd miles that may be in the given latitude, multiply the difference between the length of a degree in the next higher and lower parallels, taken from the table, by the odd miles in the given latitude, and divide their product by 60, the miles in a degree, and the quotient will be the length for the odd miles, which, added to the tabular number, corresponding with the next higher parallel, will be the length required in geographical miles. For English miles, multiply the product of the tabular number of odd miles by 2, and divide by 139, the half miles English in a degree, and proceed with the quotient as before.

* The nearest distance between any two places is an arc of a great circle, and except when the places are on the same meridian, on the equator, or ecliptic, they cannot be justly measured on the globe but by the quadrant of altitude; when the quadrant is wanting, the distance of two places may be found by

a degree of the latitude that the place lies in, taken from the preceding table, will give the distance required.

As finding the distance, appears by the preceding table to require some knowledge of decimals; it will be advisable to pass this problem when the pupil is unacquainted with that science, and proceed by prob. 12, which shows the method of finding the distance of places in all situations.

Given two places in lat. 40° N. one in 51° 42′ E. lon. and the other in 10° 12′ E. lon.; required their distance in geographical miles? Answer, $1907\frac{3}{10}$ miles.

Required the distance of two places in 30° S. lat. one of them being in 104° 15′ W. lon. and the other in 110° 45′ E. lon. in geographical miles? Answer, $7534\frac{3}{10}$ miles.

taking their distance in a pair of compasses, a piece of wire or string, and applying it to the meridian, equator, or ecliptic, which will give the number of degrees; these, multiplied by 60 for geographical miles, or 69½ for English miles will give the distance accordingly. This method is more particularly useful, where the places are more than 108° apart; and though not so just as by calculation, yet sufficiently accurate for most purposes to which globes are applied. The preceding table is calculated thus: as radius is to the length of a degree on the equator, so is co-sine of the given lat. to the length of a degree in that latitude.

What is the distance between two places in 51° 30′ lat. suppose London, where a degree is 43½ miles, and another place in lon. 180°, in English miles? Answer, 7776 miles = the greatest distance that any place can be from London, E. or W.

PROBLEM XII.

*To find the distance of two places by the quadrant of altitude.**

Bring one of the places to the meridian, screw the quadrant over it, and turn the quadrant till its graduated edge comes to the other place, then the number of degrees between the places, reckoned on the quadrant, multiplied by 60 or 69½ will give the distance in miles.

Given Jerusalem and Bombay; required their distance in geographical miles? Answer, $35\frac{1}{2}^{\circ} = 2130$ miles.

Required the distance between the Lizard Point, Cornwall, and Kingston, Jamaica, in English miles? Answer, $64\frac{1}{2}^{\circ} = 4482\frac{3}{4}$ miles.

* If the given distance exceeds 90°, the quadrant must be fixed over the antipodes of the given place, and the number of degrees between the antipodes, and the second place taken from 180°, leaves the required distance.

What is the distance between London and its antipodes, in English and geographical miles? Answer, 180°=10,800 miles geographical, and 12,510 miles English, being the greatest distance any place can be from London.

PROBLEM XIII.

*To find the bearing of one place from another by the quadrant of altitude.**

Rectify the globe for the latitude of the first place and bring it to the meridian, fix the quadrant over it, move the quadrant till its graduated edge pass over the second place; and the point of the compass that the graduated edge of the quadrant coincides with on the horizon, is the bearing required.

Given London; required the bearing of the N. point of the Island of Ceylon from it? Answer, East.

* If the distance between two places be given, and their bearing, to find the place, rectify the globe for the latitude of the first place, fix the quadrant over it, and bring its graduated edge to the point of bearing on the horizon, and under the given distance on the quadrant will be the place required.

Given London, and a place lying east from it, distance 76°; required the place? Answer, Calymere Point, N. end of the Island of Ceylon.

Required what point of the compass Cape St. Roque, NE. point of the Brazils, bears on from London? Answer, SW. by S. $\frac{1}{2}$ W.

What point of the compass does Calcutta bear on from the Cape of Good Hope? Answer, NE. by E. $\frac{1}{2}$ E. nearly.

PROBLEM XIV.

The day of the month given, to find the sun's place in the ecliptic and his declination.

Find on the horizon the day and month given, opposite to which are the degree and sign the sun is in, find the same sign and degree in the ecliptic, which is the sun's place on that day, bring it under the meridian, and the degree over it is the sun's declination for the given day.

Given the 23d of September; required the sun's place and declination?

Answer, the sun's place is the 1° ♎, Libra, and declination 0, being on the equator.

Required the sun's place and declination on the 21st of June?

Answer, the 1° ♋, Cancer, and declination 23½° N.

What is the sun's declination and place on the 24th of February?

Answer 6° ♓, Pisces, and declination 9¾° S.

PROBLEM XV.

The sun's place in the ecliptic given, to find the day of the month.

Find the sign and degree that the sun is in on the horizon, and opposite to it, in the circle for days, on the horizon, is the day of the month required.

Given the sun's place, 1° ♑, Capricorn; required the day of the month? Answer, 21st of December.

Required what day of the month the sun is in the 20° of Libra, ♎? Answer, 13th of October.

What day of the month does the sun come to the 25° of Aries, ♈? Answer, the 15th of April.

PROBLEM XVI.

*To find the difference of time between two given places.**

Bring one of the places to the meridian, set the index to the upper XII, turn the globe until the other place comes under the meridian, and the index will

* The difference of time may be found by subtracting the longitudes of the given places, if on the same side of the meridian, or adding them, if on contrary sides; then their difference, or sum, divided by 15°, because 15° are equal to an hour in time, the quotient is the hours required; and for every unit in the

point to the hour that is equal to the difference of time required. Note, if the difference of time exceeds twelve hours, then the hour to which the index points, added to twelve, will give the difference of time required.

Given London and Moscow; required the difference of time? Answer, 2 ho. 31 mi. earlier.

Required the difference of time between Kingston in Jamaica and Madras?

Answer, Madras has the time 10 ho. 29 mi. earlier than Jamaica.

What is the difference of time between Otaheite, 150° west, and Botany Bay, 153° east?

If Botany Bay is brought to the brass meridian, the index set to the upper XII. and the globe turned eastward according to its natural motion, the difference of time will be 20 ho. 12 mi. earlier than at Otaheite. But if Otaheite be brought to the meridian, and the index set to XII. and the globe turned as before, then the difference of time is 3 ho. 48 mi. Therefore this problem admits of two answers, according to the method by which it is solved.

remainder allow four minutes, which, added to the hours, will be the whole difference of time. If one of the places be on the first meridian, then the longitude of the other place divided as above, will be the difference of time; and, if to the east, the time is earlier: if to the west, the time is later.

PROBLEM XVII.

A place and the hour being given, to find what o'clock it is at any other place given.

Bring the given place, at which the hour is known, to the meridian, set the index to the given hour, turn the globe till the other place comes to the meridian, and the index will point to the hour required.

Given noon at London; required the time at Nankin in China? Answer, eight o'clock at night.

Required the time at Calcutta in the East Indies, when it is nine o'clock in the morning at London?

Answer, 44 mi. past two in the afternoon.

What o'clock is it at Quebec in North America, when it is two P. M. at Constantinople?

Answer, 24 mi. past seven in the morning.

PROBLEM XVIII.

A place and hour given, to find all those places or people that have the same hour at noon; are at breakfast, suppose nine in the morning; are at dinner, suppose three in the afternoon; tea at six; supper at ten, and have midnight all at the time given.

Place the poles in the horizon, bring the given place to the meridian, set the index to the upper XII, then

all those places that lie under the meridian have it noon; those cut by the meridian on the lower hemisphere have it midnight; turn the globe to the right until the index points to nine, and those under the meridian will have it breakfast time; turn the globe to the left until the index points to III. VI. and X. respectively, and under the meridian, at each of these hours, will be found the respective places required.

Given noon at London, required what places have the same hour, that have nine in the morning, three, four, six, &c. in the afternoon?

Answer, the twelve o'clock line passes through France, Spain, Algiers, Guinea, &c.; the nine-hour line passes through the Brazils and Greenland; the three o'clock line through Russia, Armenia, Arabia, &c.; six-hour line through Siberia, Thibet, Bay of Bengal, &c.; tenth-hour line through the Kurile Islands, New Britain, near Botany Bay, &c. and it is midnight at the eastern part of Siberia, Solitary Island in the Pacific Ocean, east end of New Zealand, &c. nearly.

PROBLEM XIX.

To find by estimation and one position of the globe, the length of the longest and shortest days and nights in any latitude between the arctic and antarctic circles.

Elevate the north pole $23\frac{1}{4}°$, bring Cancer to the

meridian; then the number of meridians* on the given parallel of latitude between the meridian and horizon being doubled, will give the hours of the day, to which add eight minutes for every odd degree that there may be over the perfect meridians, and the sum will be the length of the longest day in the latitude given, if in north latitude, and the shortest in south latitude; those lengths, in north latitude, subtracted from twenty-four, will show the shortest nights; and in south latitude, taken from twenty-four, will give the longest days in their respective latitudes.

Given the equator; required the number of meridians and the length of the longest day and longest night? Answer, 6 meridians × 2 = 12 hours longest day, 24—12 = 12, shortest night.

Required the number of meridians, the longest day and shortest night in latitude 51° 30′ north or south? Answer, 8 merid. + 4. 8 × 2 = 16 ho. + 4 × 8 = 32 mi. = 16 ho. 32 mi. longest day, and 24 ho.—16 ho. 32 mi. = 7 ho. 28 mi. shortest night.

In latitude 60° south or north, required the num-

* If the meridians on the globe are not drawn for every 15°, or if the longitude does not begin at London, count the number of the degrees between the brass meridian and the horizon, on the parallel given; divide the sum by 15, and the quotient will be the hours; and each unit (as both sides are considered) in the remainder will be equal to eight minutes.

ber of meridians, length of the longest day and shortest night? Answer, $2\frac{1}{2}$ meridians, equal 5 ho. shortest night 24 ho.—5 ho.=19 ho. longest day.

PROBLEM XX.

To find the time of the sun's rising and setting, length of the day and night on any given day and place, not in the frigid zones.*

Rectify the globe for the latitude of the place; bring the sun's place for the given day to the meridian, set the index to the upper XII, bring the sun's place to the eastern verge of the horizon, and the index will point to the hour of his rising; turn the globe till the sun's place coincide with the western verge of the horizon, and the index will point to his time of setting, double the time between his rising and noon, which will give the length of the day; this subtracted from twenty-four, leaves the length of the night.

* The hour-circles on some globes are marked double, and hence point out, at once, the rising and setting of the sun; the outer circle shows the hour of his rising and time A. M., and the inner circle that of his setting, and the time past meridian, or P. M. so that whatever hour the index points to on the outer circle for his rising, the hour under it, on the inner circle, is his time of setting.

Given London, 21st of June; required the time of the sun's rising and setting, the length of the day and night? Answer, rises 43 mi. past 3, and sets 17 mi. past 8, day 16 ho. 34 mi., night 7 ho. 26. mi.

Required the time of the sun's rising and setting, the length of the day and night at the Lizard point, Cornwall, 20th of April?

Answer, rises 1 mi. past 5, and sets 59 mi. past 6; day 13 ho. 58 mi., night 10 ho. 2 mi. from sun-setting to sun-rising.

At Aberdeen, on the 21st day of December; required the time of the sun's rising and setting, and the length of the day and night?

Answer, the sun rises at 5 mi. before 9, and sets 5 mi. past 3, being the shortest day, equal 6 ho. 10 mi., and longest night 17 ho. 50 mi.

PROBLEM XXI.

The length of the longest day given, at any place between the polar circles, to find the latitude of the place.

Bring the first degree of Cancer for north latitude, or Capricorn for south latitude, to the meridian; set the index to the upper XII, and turn the globe until the index has passed over half of the hours, &c. of the given day, then raise or depress the pole upwards or downwards, until the first degree of Cancer, if north

latitude, or Capricorn, if south latitude, coincide with the horizon, and the degree cut by the horizon, at the elevated pole, on the brass meridian, is the latitude of the place.

At what latitude is the longest day 16 ho. 34 mi.? Answer, at 51° 30′ north or south latitude.

Required the latitude of the place where the longest day is 17 ho. 50 mi.? Answer, 57° 7′ north or south latitude.

What is the latitude where the longest day is 18 ho. 36 mi.? Answer, 60° latitude.

PROBLEM XXII.

*The place and day given, to find the beginning, end, and duration of twilight.**

Rectify the globe for the given place, and fix the quadrant of altitude over it, bring the sun's place for the given day to the meridian, set the index to the upper XII, turn the globe till the sun's place

* To find where constant twilight begins, add 18° to the latitude of any place, subtract the sum from 90°, and if the sun's declination, which must be of the same name with the latitude, exceed the remainder, the twilight will continue constant, more or less.

comes to the eastern verge of the horizon. Note the time shown by the index (which is the time of the sun's rising), bring the sun's place, 18° beneath the horizon, measured by the quadrant, the graduated edge of which being brought to the sun's place, the index will then point to the time that twilight begins, the time between which and the sun's rising is its duration; turn the globe till the sun's place is 18° below the western verge, and the index will point to the time that twilight ends. If the sun's place does not come 18° beneath the horizon, twilight will continue from sun-rise to sun-set.

Given London, 20th of March; required the time that twilight begins, ends, and its duration? Answer, it begins at 4 ho. 2 mi. in the morning, ends 7 ho. 58 mi. in the evening, duration 1 ho. 58 mi.

What day does constant twilight begin at London, and when does it cease?

Answer, commences May 22, and ceases July 21.

At what latitude, south or north, does twilight continue for one night only?

Answer, at 48° 32′ latitude, south or north.

PROBLEM XXIII.

*A place, day, and hour being given, to find at what place the sun is then vertical.**

Bring the sun's place for the given day to the meridian, and mark the degree over it, then bring the given place to the meridian, and set the index to the upper XII, turn the globe to the right if the time is in the afternoon, and to the left if the time is in the forenoon, till the index points to the given hour, and the place under the mark will have the sun vertical at the time given.

Given London, June 21st, at eight o'clock, A. M.; required the place that the sun is then vertical to?

Answer, in the Arabian Sea, a little north of Cape Rasel Gat.

Required at what place the sun will be vertical on the 21st of March, when it is three o'clock in the morning at St. Helena?

Answer, near the north-west point of New Guinea.

* The sliding hour-circles, and other hour-circles on some globes, have only one circle of hours; therefore, in such cases the globe must be turned till the index points to an hour equally distant from noon as the time given, and on the opposite side of the meridian or upper XII.

When it is four, P. M. at London, on the 23d of September, at what place is the sun vertical?

Answer, on the line at 60° west longitude, north part of Amazonia.

PROBLEM XXIV.

Given the day of the month, to find all those places that have the sun vertical at their noon on that day.

Bring the sun's place for the given day to the meridian, and mark the degree over it, turn the globe quite round, observing those places that pass under the mark, which are the places where the sun is vertical that day at their noon.

Given June 21st; required those places where the sun is vertical on that day?

Answer, south point of California, north end of Cuba, Calcutta, island of Formosa, &c.

Required at what places the sun will be vertical at their noon on September 18th?

Answer, the sun passes over Guiana, Guinea, Sumatra, Borneo, &c.

At what places will the sun be vertical, on the 21st of December?

Answer, to all those Places situated on the tropic of Capricorn.

PROBLEM XXV.

*Any place in the torrid zone given, to find those two days in the year when the sun will be vertical at that place.**

Bring the place to the meridian, and mark its latitude, turn the globe till some part of the ecliptic comes under the mark, note the sign and degree, turn the globe the contrary way, till another point of the ecliptic comes under the mark, note the sign and degree likewise; find the corresponding signs and degrees on the horizon, and opposite to them, in the circle of days, will be the two days required.

Given Borneo, in the island of Borneo; required the two days in the year that the sun will be vertical there?

Answer, the 2d of April, and 11th of September.

Given Martinico, (Fort Royal), in the West Indies; required what two days of the year they have the sun vertical? Answer, the 29th of April, and 14th of August.

* The sun is vertical only to the inhabitants of the torrid zone, and there at every place twice a year, except at the first degree of Cancer and Capricorn, where he is vertical only once a year.

Required what two days of the year the sun is vertical at St. Helena?

Answer, the 5th of November, and 6th of February.

PROBLEM XXVI.

A place, month, day, and hour given, to find all those places where the sun is then rising and setting, where it is noon, midnight, beginning and ending of twilight.

Elevate the pole to the sun's declination for the given day, bring the given place to the meridian, set the index to the upper XII; if the time given be not at noon, turn the globe until the index points to the given hour, then those places under the meridian, have it noon; those under the meridian, below the horizon, have it midnight; those cut by the eastern verge of the horizon have the sun setting; those cut by the western verge have him rising; those in the upper hemisphere have it day, and on the lower have it night; those not more than 18° beneath the horizon have it twilight; and those under the sun's declination have the sun vertical at the noon of that day.

Given noon at London, the 21st of May; required at what places the sun is rising, setting, &c.?

Answer, the sun is setting to the kingdoms of Pegu, Tonquin, China, &c.; rising to the inhabitants of

Chili, New Spain, west side of the Gulf of Mexico, &c.; noon at the western part of France, east part of Spain, through several countries of Africa, &c.; midnight at New Zealand, Friendly Isles, through the Pacific Ocean, &c.; twilight ending to those 18° beneath the eastern verge of the horizon, and beginning to those situated 18° beneath the western verge.

PROBLEM XXVII.

*To find the sun's meridian altitude, day and place being given.**

Rectify the globe for the latitude of the given place, bring the sun's place to the meridian, then the number of degrees, reckoned on the meridian, between the sun's place, and that part of the horizon next to the pole that is depressed is the altitude required.

Required the sun's greatest altitude at London, on the 21st of June? Answer, 62°.

* The meridian altitude of the sun may be found, when the latitude and declination are of the same name, that is, both north or both south, by subtracting the difference between the latitude of the place given and the sun's declination, for the given day, from 90°, the remainder is the altitude; but if the declination and latitude are on opposite sides of the equator, then their sum, taken from 90°, leaves the meridian altitude.

What is the sun's meridian altitude at London, on the 21st of December? Answer, 15°.

How many degrees is the sun above the south point of the horizon at St. Helena, on the 6th of February? Answer, 90°, being in their zenith.

PROBLEM XXVIII.

To find the sun's altitude at any hour of the day and place given.

Rectify the globe for the latitude of the given place, bring the sun's place to the meridian, set the index to the upper XII, fix the quadrant over the latitude of the given place, turn the globe until the index points to the given hour, fix the globe, and turn the quadrant until the graduated edge comes to the sun's place, then the number of degrees between the sun's place and the horizon, reckoned on the quadrant, is the altitude required.

Given London, the 23d of September, at seven A. M.; required the sun's altitude? Answer, 10°.

Required the sun's altitude at Lisbon at 9 A. M. on the 25th of March? Answer, 36°.

What is the sun's altitude at London, on the 21st of May, at three P. M.? Answer, 43° 30'.

PROBLEM XXIX.

A place being given, to find the hour of the day, at any time, when the sun shines.

Rectify the globe for the latitude of the given place, set the globe in the sun, on an horizontal plane, and place it due north and south by the mariner's compass, (allowing for the variation of the needle), the hour-circle then becomes the hour-circle of a sun-dial, and the extended axis * of the globe, the gnomon or style, the middle of which shadow will point to the hour of the day required.

Another method for finding the hour of the day by the globe, when the sun shines, place, month, and day being given:

Rectify the globe for the latitude, place the globe due north and south, as in the preceding, find

* The globes that have the hour-circles drawn on them, have not the axis produced, so as to throw a shadow of sufficient length; therefore a needle, or something similar, must be placed at the extremity of the axis for a gnomon; likewise the globes that have the hour-circles moveable, the upper XII. must be brought to the graduated edge of the brass meridian, before the problem can be solved. The sliding hour-circles are particularly convenient, as their index can be taken out, and a pencil or something similar put in its place, to cast a shadow.

the sun's place in the ecliptic, and mark it with a patch, fix a needle perpendicularly in the sun's place, and bring it to the meridian, set the index to the upper XII, turn the globe about until the needle points to the sun, which is known by its not having any shadow, and the index will then show the time on the horary circle.

PROBLEM XXX.

A place, month, and day being given, to find on what point of the compass the sun will rise or set on that day.

Rectify the globe for the latitude of the given place, bring the sun's place for the given day to the eastern verge of the horizon, which will coincide with the point of the compass on the horizon that the sun rises on, turn the globe until the sun's place comes to the western verge of the horizon; which will point out on the horizon his bearing at setting.

Given London the 21st of June; required on what point of the compass the sun rises or sets on that day?

Answer, rises NE. $\frac{1}{2}$ E. nearly, and sets nearly NW. $\frac{1}{2}$ West.

Required on what points of the compass the sun rises and sets at London the 20th of March? Answer, rises due east, and sets due west.

On what points of the compass does the sun rise and set at London on the 22d of November? Answer, rises on the SE. by E. point, and sets SW. by W.

PROBLEM XXXI.

A place being given in the frigid zone, suppose the north frigid zone, to find how long the sun shines there without setting, and how long he is absent; the day of the month he begins to shine there, and the day he ceases to shine constantly; and likewise the day on which he begins to be quite absent, and the day that he begins to shine again.

Bring the given place to the meridian, find its distance from the pole, reckon the same distance from the equator, both ways, on the meridian, and place a mark where each reckoning ends; turn the globe, and observe the degree and sign of the first and second quarters of the ecliptic that come under the mark, on the N. side of the equator; their corresponding days found on the horizon will give the first and last days of his appearance, and the intermediate days show how long he shines constant. Then turn the globe until the third and fourth quarters of the ecliptic come under the second mark on the meridian, find the degree, sign, day, and intermediate days, as in the first

case, which will likewise show the first, last, and number of days of his absence.

Required the length of the longest day at the N. Cape, lat. 71° 30′, on what day it begins, and what day it ends? Answer, the longest day is 77 natural days; begins 13th of May, and ends the 29th of July.

What is the longest day in lat. 80° N., when does it begin and end, the longest night, &c.? Answer, the longest day is 134 days, viz. from the 15th of April to the 27th of August; the longest night is 128 days, begins the 18th of October, and ends the 23d of February.*

Required the longest day at the N. pole, and the longest night, with the day that each begins? Answer, the longest day is 187 days, begins the 20th of March, ends the 23d of September; the longest night 178 days, begins the 23d of September, and ends the 20th of March.

* The reason of the longest days and longest nights, in the frigid zones, not being equal, is because the sun passes through the southern signs sooner than the northern.

PROBLEM XXXII.

*To find that part of the equation of time which arises from the obliquity of the ecliptic, day and month being given.**

Bring the sun's place to the meridian and fix the globe, reckon the number of degrees between Aries and the brass meridian on the equator and ecliptic, allowing four minutes for each degree of their difference, which will be the equation required. If the number of degrees on the ecliptic exceed those on the equator, the sun is faster than the clock; if less, the sun is slower than the clock.

Given the 8th of September; required the equation of time, and whether the clocks show the time faster or slower than the sun? Answer, the clocks are 4 mi. 47 sec. faster than the sun by the globe, but by the table 2 mi. 41 sec.

Given the 15th of April, the 16th of June, the 31st

* The equation of time, or difference between the time shown by a well-regulated clock and true sun-dial, depends on two causes, namely, the obliquity of the ecliptic, and the unequal motion of the earth in it, a description of which would be too diffuse for a treatise on the globes; the result would, however, show the reason of the tables and globe being so different. See Ferguson's Astronomy, c. xiii.

of August, and the 24th of December: required the equation of time for these days? Answer, on the above four days in the year, the sun and clocks show the same time by the table; but by the globe the 20th of March, the 21st of June, the 23d of September, and the 21st of December, show the same time; being the time that the sun enters Aries, Cancer, Libra, and Capricorn.

The following table shows the difference of time between a well-regulated clock or watch, and the sun; the former, if a good time-piece, shows mean time, that is, it keeps the same motion all the year; whereas the sun, as observed in the preceding note, moves sometimes slower, and at other times quicker, as may be seen in the table, which is equated or mean time; and is calculated for every fifth day of the first year after leap-year; and is sufficiently exact for setting time-pieces for any year. The method of reading it may be understood by an example:—What is the difference of time between a well-going time-piece and the sun, on the 30th of January? In the left hand column, under days, find the given day, and in a line with it under the given month is 13 mi. 53 sec. the equated time required; and at the top of the column under the month, is clocks faster, which shows that on the given day it should be 13 mi. 53 sec. after twelve by the clock, when it is noon by the sun. The application of this table is particularly described in my Heavens Displayed, p. 42, &c.

An Equation Table for the first Year after Leap Year, for every fifth Day.

	JANUARY, Clock faster.		APRIL, Clock faster.		JULY, Clock faster.		OCTOBER, Clock slower.		
Days.	M.	S.	M.	S.	M.	S.	M.	S.	Days.
1	4	21	3	49	3	22	10	30	1
5	6	11	2	37	4	5	11	43	5
10	8	17	1	11	4	51	13	5	10
15	10	8	0	8	5	28	14	14	15
20	11	42	1	17	5	52	15	10	20
25	22	58	2	16	6	2	15	49	25
30	13	53	3	2	5	57	16	10	30
	FEBRUARY Clock faster.		MAY, Clock slower.		AUGUST, Clock faster.		NOVEM. Clock slower.		
1	14	9	3	10	5	50	16	13	1
5	14	32	3	36	4	5	16	10	5
10	14	41	3	56	4	51	15	47	10
15	14	31	4	1	5	28	15	2	15
20	14	4	3	51	5	52	13	56	20
25	13	21	3	28	6	2	12	30	25
30			2	53	5	57	10	47	30
	MARCH, Clock faster.		JUNE, Clock slower.		SEPTEM. Clock slower.		DECEMBER Clock slower.		
1	12	36	2	36	0	23	10	24	1
5	11	42	1	57	1	41	8	47	5
10	10	26	1	2	3	22	6	33	10
15	9	1	0	6	5	6	4	10	15
20	7	32	1	5	6	50	1	40	20
25	5	59	2	9	8	33	0	49	25
30	4	26	3	10	10	11	3	16	30

NOTE. That it will appear from the above table, that from the 24th of December until the 15th of April the clock will be before the sun; and from that time to the 16th of June the sun will be before the clock. From the 16th of June until the 31st of August the clock will be again before the sun; and from thence to the 24th of December the sun will be faster than the clock.

PROBLEM XXXIII.

To find in what climate any given place, not in the frigid zones, is situated.*

Rectify the globe for the given latitude, bring the first degree of Cancer to the meridian, set the index to the upper XII, turn the globe until Cancer comes to the verge of the horizon, the index will point to the time of his rising, the time between which and noon being doubled, gives the length of the longest day at that place, from which take twelve hours, and the half hours contained in the remainder will answer to the number of the climate that the given place lies in.

What climate is Gibraltar in? Answer, the fifth climate.

Required the climate that London is in? Answer, the ninth.

Given Peterhead, the easternmost town in Scotland; required the climate it is in? Answer, the 12th.

* Climates are tracts of the earth's surface going quite round the globe, bounded by lesser circles, running parallel to the equator, being thirty in number, twenty-four of which are of such a breadth, that the artificial day in each succeeding climate is increased half an hour, and are situated between the equator and the polar circles; the other six have their days increased each a month, and lie between the polar circles and their poles.

FIRST PART OF ,

A Table of Climates, differing from each other half an hour in their longest day; situated between the equator and polar circles.

Climate.	Latitude.		Longest Day.		Climate.	Latitude.		Longest Day.	
	o	′	*ho.*	*mi.*		o	′	*ho.*	*mi.*
1 ends	8	34	12	30	13 ends	59	59	18	30
2	16	44	13	—	14	61	1t	19	—
3	24	12	13	30	15	62	26	19	30
4	30	48	14	—	16	63	22	20	—
5	36	51	14	30	17	64	10	20	30
6	41	24	15	—	18	64	50	21	—
7	45	32	15	30	19	65	22	21	30
8	49	2	16	—	20	65	48	22	—
9	51	59	16	30	21	66	5	22	30
10	54	30	17	—	22	66	21	23	—
11	56	38	17	30	23	66	29	23	30
12	58	27	18	—	24	66	32	24	—

SECOND PART.

Climates differing from each other a month in their longest day; situated between the polar circles and their poles.

Climate.	Latitude.		Longest Day.		Climate.	Latitude.		Longest Day.	
	o	′	Mths.	Days.		o	′	Mths.	Days.
25 ends	67	18	1 or	30	28	77	40	4 or	120
26	69	33	2	60	29	82	59	5	150
27	73	5	3	90	30	90	—	6	180

The first part of the table of climates is found by the following rule.

As tangent of the sun's greatest dec. 23° 28′, is to radius 90°;

So is S. of the sun's ascensional difference, to tangent of the lat. where the calculated climate ends.

To find the sun's ascensional difference.

Subtract six hours from half of the length of the longest day in the required climate, and the remainder turned into degrees, will be the sun's ascensional difference for that climate.

Example. The longest day at the end of the second climate is 13 hours; from the half of which take 6 hours: the remainder is 30 mi. which are equal to 7° 30′, the ascensional difference, for calculating the latitude that the second climate ends in.

To construct the second part of the table of climates.

Take half the number of the days contained in the given climate, reckon this number off from the 21st of June both ways, that is, towards July, and towards the 1st of June; find from an ephemeris the declination answering to the two days where the reckoning ends; add the declinations thus found together, and subtract half their sum from 90°, the remainder will be the latitude where the assigned climate ends; but

as the declination of the sun varies, that is, it differs for four years in succession; therefore a mean of the declinations of leap-year, and the three following years, must be taken, to be correct.

PROBLEM XXXIV.

To find in what climate any place in the frigid zone is situated.

Find, by Problem XXXI., the time that the sun shines constant at the place given, which, if less than thirty days, the place is in the 25th climate; if between thirty and sixty days, it is in the 26th climate; if between sixty and ninety days, the 27th, &c. each exceeding another thirty days.

Given the north Cape, Lapland; required what climate it is in? Answer, the longest day being seventy-seven days, answers to the 27th climate.

In what climate is Nova Zembla, lat. 78° N.? Answer, the 28th.

What climate is Spitsbergen in, at lat. 80° N.? Answer, the 29th.

PROBLEM XXXV.

A place and its distance from another place being given, to find all the places that are at the same distance from it.*

Bring the given place to the meridian, and fix the quadrant over it, reckon the distance given on the quadrant, beginning at the meridian, and place a mark at the end of the reckoning, fix the globe, and turn the quadrant quite round, observing what places pass under the mark, which lie at equal distances with the place given.

Given London; required the principal places that are at the same distance from it, as the south point of

* If the distance is given in geographical miles, they must be brought into degrees by dividing them by 60; if in English miles, multiply them by 2 and divide by 139, as in note at Problem X, the quotient will be degrees, and the remainder miles in the former case; in the latter case, the quotient will be degrees and the remainder half miles, which divide by 2 to bring them to miles. If the given distance exceed 90° or 108°, fix the quadrant of altitude over the antipodes of the given place, and subtract the given distance from 180°, and proceed with the remainder as the problem directs. This problem may be performed by taking the given distance from the equator or meridian in a pair of compasses or a string, one end or point of which applied to the first place, and the other carried round, will point out the places required.

Italy, which, by the quadrant, is 17° 45′? Answer, the north part of Iceland, Fez in Africa, Corfu, Petersburg, and the north end of the Gulf of Bothnia, are nearly the same distance.

Required what places are as distant from Kingston, Jamaica, as London is, it being about 4110 geographical miles? Answer, the Marquesas and Easter Island, in the south Pacific Ocean; Ascension, in the south Atlantic; Carthagena, in Spain; and the Shetland Islands, north of Scotland, are nearly at the same distance.

PROBLEM XXXVI.

A place and its distance from a second place, with the latitude of the second place and the hemisphere it is in, being given, to find the place.

Bring the given place to the meridian, fix the quadrant over it, and mark on it the given distance, reckoning from the meridian, place a lead pencil * on that side of the meridian on which the second place lies, turn the globe the contrary way, the pencil at the

* If the second place lies under any of the parallels of latitude marked on the globe, the part relating to the pencil is not necessary, the parallel answering to its circular mark.

same time making a circular mark of sufficient length, by estimation, bring the given place back to the meridian, and turn the quadrant until the mark on it cut the pencil mark, and their point of section will be the place required.

Given London, distant from another place, lying easterly, 18° 30′ in lat. 59° 56′ N.; required the place? Answer, Petersburgh, capital of Russia.

Given Madrid, in Spain, distant from another place 41°, which lies easterly in lat. 37° 30′ N.; required the place? Answer, near the south-west shore of the Caspian sea.

A place situated on the western hemisphere, in lat. 70° 56′ S. distant from London 61° 30′; required the place? Answer, Ascension Island, in the South Atlantic.

PROBLEM XXXVII.

A place and its distance from a second place, with the longitude of the second place given, to find the place.

Bring the given place to the meridian and fix the quadrant over it, and mark off the distance on the quadrant, reckoning from the meridian; bring the given longitude to the meridian, and, with a pencil or chalk, draw a line by the edge of the graduated side of the

meridian of sufficient length, by estimation, turn the globe until the given place is brought back to the meridian, then turn the quadrant until the mark on it cut the line made by the pencil, and at their point of section will be the place required.*

Given London, distant from another place 41° 50′ in lon. 52° 55′ E.; required the place? Answer, Ispahan, the capital of Persia.

Given Paris, distant from another place 62° in lon. 60° 16′ W.; required the place? Answer, Fort Royal, in Martinico, West Indies.

Given Stockholm, in Sweden, distant from another place 51°, in lon. 71° 12′ W.; required the place? Answer, Quebec, in Canada, North America.

PROBLEM XXXVIII.

The day of the month and hour that a lunar eclipse begins being given, to find where it will be visible.†

Find, by Problem XXIII, the place where the sun

* If the second place lies under any of the meridians marked on the globe, the mark with the pencil may be left out, as the meridian answers the same purpose.

† Astronomers have divided the face, or disc, of the sun and moon into twelve equal parts, called digits, by which the quantity of an eclipse is chiefly specified.

will be vertical at the time when the eclipse begins; rectify the globe for the antipodes of that place, keeping the place at the meridian, and set the index to the upper XII, turn the globe until it points to the under XII, then all those places above the horizon will have the eclipse visible.*

Given an eclipse of the moon, the 22d of July, 3 ho. 25 mi. P. M.; required at what place it will be visible? Answer, at New Holland, over the most art of Asia, the east part of Africa, the Indian Ocean, &c.

Given an eclipse of the moon, the 20th of March, at 10 ho. P. M.; required what places will have it visible? Answer, the east part of America, the Atlantic and Indian Oceans, Europe, Africa, and the most part of Asia.

* Eclipses of the moon are seen from all parts of that hemisphere of the earth which is next to her, and are equally great to each of those parts; but the sun's eclipses are visible only to that small portion of the hemisphere next to him, whereon the moon's shadow falls; the moon's dark shadow covering only a spot on the earth's surface, about 180 miles broad, when her diameter appears largest and the sun's the least, and the total darkness can extend no farther than the dark shadow covers.

PROBLEM XXXIX.

The day of the month and hour that a solar eclipse begins, of not less than eight or nine digits, being given, to find the places where it is visible.

Find the place where the sun will be vertical at the given time, by Prob. XXIII, and rectify the globe for the latitude of that place. The eclipse will be visible to most of the places above the horizon.

Given an eclipse of the sun, the 21st of February, at 9 ho. 5 mi. P. M.; required the countries to which it will be visible? Answer, in the Pacific Ocean, North America, west part of South America, Botany Bay, and the north-east parts of Asia.

Given an eclipse of the sun, the 11th of February, begins at 27 mi. past 10 in the morning, required those places where it will be visible? Answer, Europe, Africa, the Indian and Atlantic Oceans, &c.

NAUTICAL PROBLEMS.

1. Single courses by *plane-sailing*. The name is deduced from the supposition that the earth is an extended plane; and hence not of use in navigation except in short voyages, or near to the equator; where the degrees of latitude and longitude are nearly alike; it

is also described at p. 107, how far the bearings that are determined by an angle of position (which are used here) are from the truth; this mode therefore is only a geographical species of navigation; but sufficiently calculated to show the young student something of the method pursued by mariners to carry on their noble art of navigation; which, to a native of the British isles, is an important consideration, when we reflect that our ships navigate all parts of the habitable globe; and that so many thousands of our brave countrymen are now so laudably employed in protecting and preventing the subjugation not only of Britain, but of the Christian world. (1810.)

On entering on this subject, the following phrases ought first to be understood.

DIFFERENCE OF LATITUDE, is the northing, or southing, made during the course, and is represented by the perpendicular of a triangle, and the meridians on the globe. See page 7.

DEPARTURE FROM THE MERIDIAN, is the easting, or westing, made during the course, and is represented by the base of a triangle, and the lines that run E. and W. on the globe.

DISTANCE SAILED, is the track that the ship runs through during the course; and is represented by the hypothenuse of a triangle; it is also called the rhumb line, or point of the compass that the ship sails on.

THE SHIP'S COURSE is the angle that she makes with the meridian; and is represented by the angle opposite to the base of a triangle. See p. 6.

In a ship, looking towards the stem, or the way that she sails,

STARBOARD, signifies the right-hand side;

LARBOARD, the left-hand side.

FORWARDS, or *Afore*, is towards the stem, or head of the ship.

AFT, or *Abaft*, is towards the hinder part, or stern, where the cabin and rudder are situated.

The WINDWARD, or *weather side*, is the side of the ship on which the wind blows; and the other side is called the leeward, or lee-side.

The shore on which the wind blows, is called the *lee shore;* and is always dangerous for ships on it in a tempest. The east coast of Britain is a lee shore when the wind is easterly; and in the British Channel, the south coast of Britain is a lee shore, when the wind is southerly; and the French coast, on it, is the same when the wind is northerly.

PROBLEM XL.

The place that the ship sails from, and its latitude, with the course and distance sailed given, to find the difference of latitude, and hence the latitude that the ship is come to.

Rectify the globe for the given place, and bring it to the meridian; fix the quadrant over it, and lay its graduated edge by the course on the horizon; reckon off the distance on the quadrant, beginning at the meridian; make a mark on the globe where the reckoning ends, and turn the globe till the mark comes to the meridian; then the number of degrees between the lat. of the given place and the mark, will be the difference of latitude required.

NOTE.—If the ship is sailing from the equator, this difference is to be added to the latitude of the given place for the ship's latitude; if the latitude of the first place be on the equator, then the difference found is the latitude of the second place; if she is proceeding towards the equator, it is to be subtracted; and if she has crossed the equator, the latitude of the given place is to he taken from the difference of latitude found by the problem, and the remainder will be the latitude come to; and of a different name from that given.

Suppose a ship sails from the Lizard Point, in lat. 49° 57′ N.—S.S.W. 600 miles (or 10°); required the difference of latitude, and the latitude come to? Answer, the difference of latitude is 8°, and as the ship is sailing southward, or towards the equator, it is to be subtracted from the latitude of the place, and leaves 41° 57′ N. for the latitude come to.

Suppose a ship sails from a port of Guinea, in 5° N. lat. on a S.W. course 840 miles (14°); required the difference of latitude, and the latitude come to? Answer, the difference of lat. is 9° 20′, and as she has sailed across the equator, the lat. of the given place is to be subtracted from it; and the remainder 4° 20′ S. is the latitude come to.

PROBLEM XLI.

The latitude and longitude of a place that a ship sails from, her course, and distance sailed, being given, to find her departure from the meridian; and hence the longitude come to.

Rectify the globe for the lat. of the given place, bring it to the meridian, and screw the quadrant of altitude over it, make its graduated edge coincide with the ship's course on the horizon, reckon off the distance sailed on the quadrant, make a mark on the

globe where it ends, mark the degree on the equator cut by the meridian, turn the globe till the mark on it made for the distance sailed comes to the meridian, then the number of degrees found on the equator, between the mark on it and the brass meridian, will be the departure required.

NOTE.—To find the longitude come to. If the ship has sailed from the first meridian, the departure found added to the longitude left, will be the longitude in. If she has been sailing towards the first meridian, then the departure is to be taken from the longitude left, and the remainder is the longitude come to. If the place that the ship left was on the 1st meridian, then the departure is the longitude in; and if in the course sailed she has passed the first meridian, then the longitude of the place is to be subtracted from the departure, and the remainder will be the longitude come to: and of a different name with the longitude left.

Suppose a ship sails from 20° N. lat. and 30° W. long. on a N. W. course 900 miles; required her departure and longitude come to?—Note, when the distance is given in miles, they must be brought into degrees by dividing them by 60, the miles in a degree. Answer, her departure is 12° 30′; and as she sailed westward from the first meridian, it is to be added to the longitude left, the sum of which is 42° 30′ W. for the longitude come to.

A ship in lat. 40° S. and on the first meridian, sails S.W. by W. 1200 miles; required her departure and longitude come to? Answer, her departure is 26° W. and as she sailed from a place on the first meridian, her departure and longitude come to, are the same.

PROBLEM XLII.

A place and its latitude, and the difference of latitude and course sailed, being given, to find the distance sailed.

Rectify the globe for the given place, and bring it to the meridian; screw the quadrant over it, placing it by the course on the horizon; draw a pencil line by the side of the quadrant, of sufficient length by estimation; reckon off the difference of latitude on the meridian; mark the place where it ends; turn the globe till the mark comes to the pencil line made by the edge of the quadrant, making a mark where they come in contact; turn the globe back till the given place comes to the meridian (placing the quadrant as at first); then the number of degrees on it, between the meridian and the mark on the pencil line made by the edge of the quadrant, will be the distance required.

A ship in lat. 40° N. lon. 60° W. sails N.E. till her difference of lat. is 10°; required the distance sailed? Answer, 18°=1080 miles. If the difference of lat. and

at any of the parallels drawn on the globe, the pencil line is unnecessary; as the distance sailed will be the number of degrees between the place given and where the quadrant crosses the parallel.

Suppose a ship sails from 20° S. lat., and 30° W. long. on a S.S.E. course, till she has made 20° difference of latitude; required the distance sailed? Answer, 21°, or 1260 miles.

PROBLEM XLIII.

The latitude and longitude of a place, with the difference of latitude and distance sailed, given, to find the ship's course.

Rectify the globe for the lat. bring the given place to the meridian; reckon off the degrees of the difference of latitude on the meridian, making a mark where it ends; place a pencil at the mark and turn the globe, the pencil making a line of sufficient length by estimation; turn the globe back till the given place comes to the meridian, screw the quadrant over it, then reckon the given distance on the quadrant, bring the degrees where it ends to the line made by the pencil; and the quadrant properly adjusted will then coincide on the horizon with the course required.

If the difference of latitude ends at any parallel projected on the globe, the pencil line is not necessary.

Suppose a ship in 40° lat. N. and 60° long. W. sails between the N. and E. till she has made 10° difference of lat. and 1080 miles in distance sailed; required her course? Answer, N.E.

Admit a ship sails from 20° S. lat. and 30° W. long. between the S. and E. till her difference of lat. is 20°, and distance sailed 1260 miles; required her course? Answer, S.S.E.

2. The two following Problems consist of several courses, and are therefore called *Traverse Sailing*; showing the manner in which ships proceed, when obstructed by the land or contrary winds.

PROBLEM XLIV.

The port that a ship sails from, with any number of places between which no land intersects, and where a ship may stop, or take a fresh bearing from during a voyage, being given, to find the ship's courses, (or points of the compass, by the quadrant of altitude or angle of position) that she sails on, and the number of miles she will have to run through, with the time it takes, supposing her to sail at a given mean rate per hour.

Rectify the globe for the place that the ship sails from, and bring it to the meridian, fix the quadrant

over it, and lay its graduated edge over the second place, the number of degrees between which and the first place is the length of the first course, which note; and the point of the compass, on the horizon, that coincides with the graduated edge of the quadrant, is its bearing, or the point that the ship sailed on. Rectify the globe for the second place, fixing the quadrant over it as before; proceed in this manner through the respective courses, noting their lengths and bearings; multiply the sum of the length of the courses by 60, and the product will give the geographical miles of the voyage, which divide by the given miles that the ship sails per hour, and the quotient will be the hours of the voyage; these divided by 24, the hours in a day, will give the days that the voyage was in completing. If the length of each course be multiplied by 60, it will show its length in miles.

Suppose a ship takes her departure from the Lizard Point, in Cornwall, lat. 49° 57′ N. and sails direct to Cape Finisterre, in Spain; from that to the south-west point of the Island of Teneriffe, one of the Canaries; from that to Cape Frio, near Rio Janeiro, in the Brazils, South America; from thence to the Cape of Good Hope, south point of Africa; from that to the north-west end of the island of Sumatra; and from thence to the mouth of the western branch of the Ganges, near Calcutta, in Bengal. Required the points of

the compass that she steered on each course, with their respective lengths, and the number of miles she run through in the whole, with the length of the voyage, supposing her to sail, at a mean rate, 8 miles per hour? Answer, from the Lizard Point to Cape Finisterre, 7° 30′, bears SSW.$\frac{1}{2}$W.; from Cape Finisterre to Teneriffe, north-west point, 15° 30′, bears SSW. $\frac{1}{4}$ W.; from that to Cape Frio, 56°, bearing SSW. $\frac{1}{2}$ W.; from Cape Frio to the Cape of Good Hope, 53°, bears SE. by E. $\frac{1}{2}$ E.; from that to the north-west end of Sumatra, King's Point, 82°, bearing ENE. $\frac{3}{4}$ E.; and from thence to the mouth of the Ganges, 17° 30′, bearing NNW. $\frac{1}{4}$ W. Miles run through on the whole 13,890; and the length of the voyage 72 days 8 hours.

If a ship, in sailing from Plymouth, in lat. 50° 25′ N. to Alexandria, in Egypt, touch at the following places, viz. Cape Finisterre, in Spain; Cape St. Vincent's, in Portugal; north point of Africa; Gibraltar; south point of Sardinia; and Malta: required the length of each course, and the points of the compass that she sailed on, the whole distance run, and the length of the voyage, admitting that she sails uniformly 7 miles an hour? Answer, from Plymouth to Cape Finisterre, 8° 30′, bears SSW.; from that to Cape St. Vincent, 6°, bears S.; from Cape St. Vincent's to the north point of Africa, 2° 40′, bears SE. by E. $\frac{1}{2}$ E.; from that to Gibraltar, 1°, bears

NE. ½ E.; from Gibraltar to the south point of Sardinia, 11° 30′, bears ENE. ¼ E.; from thence to Malta 5°, bears SE. ¾ E.; and from thence to Alexandria, 15°, bearing ESE. ¾ E. The distance run 2980 miles, and the length of the voyage 17 days 17 hours.

PROBLEM XLV.

The port that a ship sails from, with the bearing and distance of each place that she touches at, given, to find the places.

Rectify the globe for the latitude of the given port, fix the quadrant over it, and lay its graduated edge to the point of the compass on the horizon that the second place bears from the first, then under the distance on the quadrant is the second place; rectify the globe for the second place, and fix the quadrant over it, directing it to the point on which the third place bears from the second, and under the distance, on the quadrant, of the third place is the third place. Proceed in this manner through all the courses, and under each distance on the quadrant will be found the respective places required.

Suppose a ship sails from the Lizard Point to Calcutta, in the East Indies, on the following courses, or

points of the compass: first course, SSW. ½ W.; distance 7° 30′; second, SSW. ½ W. distance 15° 30′; third, SSW. ½ W. distance 56°; fourth, SE. by E. ½ E. distance 53°; fifth, ENE. ¾ E. distance 82°; sixth NNW. ¼ W. distance 17° 30′: required the name of each place that she changed her course at? Answer, Cape Finisterre, in Spain; Teneriffe, Cape Frio, Cape of Good Hope, north end of Sumatra, and the mouth of the Ganges, western branch.

If a ship, in sailing from Plymouth to Alexandria, in Egypt, makes the following courses: from Plymouth, first course, SSW. distance 8° 30′, second, S. distance 6°; third, SE. by E. ½ E. distance 2° 40′; fourth, NE. ½ E. distance 1°; fifth, ENE. ¼ E. distance 11° 30′; sixth, SE. ¾ E. distance 5°; and seventh, ESE. ¾ E. distance 15°: required the places that limited each course? Answer, Cape Finisterre, Cape St. Vincent's, north point of Africa, Gibraltar, south point of Sardinia, Malta, and Alexandria.

NOTE—That the angle of position between the two places, by which the bearing in the preceding problems are solved, is an angle at the zenith of one of the places, formed between the brass meridian and the quadrant of altitude passing through the other place, and is measured on the horizon, and is very different from the true bearing of places, by the mariner's compass, used in navigation; which however cannot be applied on globes, except on those that have the rhumb lines drawn on them; or by means of a sliding, glo-

PROBLEM XLVI.

To find the sun's declination by the analemma, day and month being given.

Bring the analemma to the meridian, and the degree over the given day is the declination required.

Required the sun's declination on the 25th of August? Answer, 10° 46′ N.

What is the sun's declination on the 23d of May? Answer, 20° 36′ N.

PROBLEM XLVII.

*To find by the analemma the sun's place in the ecliptic, and his right ascension, day and month given.**

Bring the analemma to the meridian, and mark it over the given day, turn the globe until a point of the ecliptic, of that quarter which corresponds with the

bular protractor, which is only a moveable spherical compass, with its thirty-two points, formed in brass, and furnished with a proper index, and means to apply and fix it to any part of the brass meridian.

* Right ascension of the sun is his distance from the 1° of Aries, reckoned on the equator eastward quite round the globe.

given month, comes under the mark which points out the sun's place; and the number of degrees reckoned on the equator, from Aries to the meridian, is his right ascension.

What is the sun's place and right ascension on the 23d of July? Answer, the sun's place is in the 1° of Leo ♌, and right ascension 122° 10′.

Required the sun's place and right ascension on the 26th of September? Answer, the sun's place is in the 4th degree of Libra ♎, and right ascension 184°.

PROBLEM XLVIII.

*The day, month, and latitude given, to find, by the analemma, the time of the sun's rising and setting.**

Rectify the globe for the latitude given, bring the middle part of the analemma to the meridian, set the index to the upper XII, turn the globe until the day given on the analemma coincides with the horizon, and the index will point to to the time of the sun's rising, the complement between which and XII. will be the time of his setting.*

* If the southernmost part of the analemma be brought to the horizon first, then every day throughout the year may be

Given lat. 51° 30′ N. 20th of March, 21st of June, 21st of July, and 21st of December; required the time of the sun's rising and setting on these days? Answer, 20th of March, rises and sets at 6; 21st of June, rises 43 mi. past 3, and sets 17 mi. past 8; 21st July, rises 4 mi. past 4, and sets 56 mi. past 7; and 21st of December, rises 8 mi. past 8, and sets 52 mi. past 3.

PROBLEM XLIX.

THE USE OF THE SLIDING HOUR-CIRCLE, OR MOVEABLE HORIZON.

This hour-circle being moveable, by means of the groove at the back of the meridian, the south pole can be elevated with the same facility as the north pole; and hence problems can be performed on the southern hemisphere with as much convenience as on the northern.

Several phenomena may be exhibited by the globe more readily, by having the hour-circle moveable; thus slide the circle from the pole to any other part of the

brought progressively to coincide with the horizon, and the time of the sun's rising and setting found as above; for every day of the year, in all places not situated within the polar circles.

meridian, hang the globe up so as its horizon may be in a perpendicular position, bring the sun's place for any given day to the meridian, and elevate the pole for his declination on that day, place a lighted candle* at a considerable distance from the globe, at the same height with its centre, and in the plane of the meridian it will exhibit all the phenomena of the natural globe of the earth for the given day. By revolving the globe on its axis, from west to east, it will appear that all places, emerging out of the dark hemisphere into the luminous one at the western part of the horizon, will see the sun rising; when at the meridian it will be noon; and when they come to the eastern verge of the horizon, they will see the setting sun.

When any given place is on the meridian, set the index to the upper XII, and turn the globe slowly round, it will show the natural motion and position of that place at all hours of the day and night; at what time the sun rises and sets to it, the length of the day and night, likewise in what places the sun does not rise or set, whence all the varieties of the seasons throughout the year, in every climate, &c. are exhibited as on the natural earth.

* This phenomenon should be exhibited in a room that has no light, except the candle; and it will show more strikingly, if the candle be placed in a dark lanthorn.

The farther use of the circle is, that having placed on it the points of the compass, if the globe and hour-circle are moved, so as to bring any given place under its centre, it can be seen by inspection upon what part of the compass any place bears from it, and therefore in some measure supplies the use of a quadrant of altitude, as the outer part of the circle represents the horizon of the place that its centre stands over.

To find the meridian altitude of the sun by the sliding hour-circle, time and place being given.

Rectify the globe for the declination answering to the given day, place the centre of the hour-circle over the place, and the angle made by an imaginary line rising vertically from the place through the centre, and the horizon will be the altitude required, or the distance reckoned on the meridian, between the centre of the circle and the point of the horizon that is of the same name with the latitude of the place, is the meridian altitude, which for London, at the winter solstice, will be found 15°, for the equinox 38½°, and for the summer solstice 62°.

PROBLEM L.

*To find the angles that the hour lines of a horizontal dial make with the horizon, and hence the means and method of constructing one for any given latitude.**

Rectify the globe for the latitude given, (then the pole will have the same elevation above the horizon as the gnomon, or stile of the dial must have above the

* From the following method and elements to construct a horizontal dial. Draw (on a piece of paper, board, stone, brass, &c. which is designed for the plane of the dial) a circle with the chord of 60° taken from the plane scale, suppose Gunter's, cross this circle at right angles, with two lines passing through its centre; one of which will represent the meridian north and south line, or twelve o'clock line, the other the east and west, or six and six-hour line; divide this circle for the hours, if for the latitude of London, as in the following table, viz. take in a pair of compasses (from the same line that the chord of 60° was taken from) 11° 51′, and with one point in the north end of the twelve o'clock line, mark off on both sides of it the 11° 51′ taken between its points; through which, from the centre of the circle, draw lines, which will represent the eleven and one o'clock hours, then take 24° 19′ from the same scale, and apply as before; through which likewise draw lines from the centre to represent the ten and two o'clock hour lines, proceed in this manner to the number of hours necessary for the latitude, which for London, (the longest day being less than seventeen hours)

plane thereof, which must always be equal to the latitude given), bring the equinoctial colure to the brass meridian, set the index to the upper XII, thus the meridian represents the twelve o'clock line, turn the globe until the index points to a quarter past twelve, look what degree the colure cuts on the horizon, which is equal to the angle made by it; proceed to turn the globe until the index points to half past twelve, three quarters, one o'clock, &c. to six, marking at each time the angle made on the horizon, reckoning from the south point; and the distance that any hour, or part of an hour, is from twelve in the afternoon, the same distance, or angle, any time equally distant from noon, will be in the forenoon; or the colure may be brought back to the meridian, and the problem repeated on the eastern hemisphere for the hours in the forenoon. Ob-

from four in the morning to eight in the evening, will be sufficient; the quarters, &c. may be found from the globe and applied progressively, or placed after the hours are determined. The gnomon must be placed in the meridian line, its elevated part towards the north, if for north latitude, and the contrary for south latitude, its slant side rising from the centre of the dial, and its height above the plane of the dial, or the angle that it makes with the meridian, must always be equal to the latitude of the place, which, for the above, is, 51° 30′; which dial will answer quite round the earth on that parallel, and likewise on the same parallel south.

serve likewise, that the angle made by the five o'clock line in the afternoon, from the south, will be equal to the angle made by the seven o'clock line, in the afternoon, from the north; and the four o'clock line equal to the eight o'clock line in the evening, &c. Also that the seven, eight, &c. hour-lines in the afternoon will make the same angles, from the north, as the five, four, &c. hour-lines in the morning.

Globes that have the meridians drawn for every 15° will, at one position, show the angles that the hour-lines make with the horizon, if the colure is brought to the meridian, and will appear as in the following table, for the latitude of London.

Hours.		°	′	
For	12	0.	0	
... 11 and	1	11	51	dist. from the 12 o'clock
... 10 ...	2	24	19	line, or from the south
... 9 ...	3	38	3	point of the horizon.
... 8 ...	4	53	36	
... 7 ...	5	71	6	
... 6 ...	6	90	*	distance from the north
... 5 ...	7	71	6	point of the horizon.
... 4 ...	8	53	36	
... 3 ...	9	38	3	&c.

CHAP. IV.

The Rise and Progress of Astronomy; with an Account of the various Systems that have been introduced into the world, &c.

THE origin of this science has afforded much contention among the learned of different nations, each setting up their prior claim, as the Babylonians, Egyptians, Grecians,* &c.

The Babylonians were the first who made observations on the stars, by whom, according to Struyk's catalogue, an eclipse of the moon was observed 721 years before Christ; and it appears from history, that the Egyptians had their first knowledge of astronomy from the Babylonians.

The Greeks had their astronomical knowledge from Egypt; for Thales,† Pythagoras, Eudoxus, and others were instructed in this science in Egypt.

* The Chinese, according to their records, understood the phenomena of the celestial objects at a much earlier date than the Babylonians, as they have an account of an eclipse that happened 2155 years before the Christian era; but how far their history can be depended on is doubtful.

† Thales flourished in Greece about 600 years before Christ.

Pythagoras, who lived in society with the Egyptian priests, who, at that time, were men of the most profound learning, was initiated into their religion and science, and carried home from thence the true system of the world, (about 450 years before Christ). This system taught, that the earth and planets turned round the sun, which was fixed in the centre, and that the diurnal motion of the sun and stars were not real, but apparent, arising from the motion of the earth on its axis.

The sciences were, however, much neglected by succeeding philosophers, particularly astronomy, so that of all the observations of eclipses, for the space of nearly two thousand years, that were sent from Babylon by Callisthenes, Ptolemy could recover but very few.

But although astronomy was not generally understood, yet it was received and cultivated by some; and the Pythagorean sect more particularly flourished in Italy many years.

The Ptolemies, kings of Egypt, were great patrons of learning; under them an academy for astronomy was established at Alexandria, which produced many great men, of whom was Hipparchus, who calculated the eclipses of the sun and moon that were to happen for six hundred years.

When the Saracens* conquered Egypt, and brought Alexandria under their jurisdiction, they took astronomy, with other sciences and liberal arts, under their protection, translating part of them into their own (the Arabian) language; afterwards they conquered Spain, and restored astronomy to the western nations of Europe, which, before this time, they had almost lost.

About the year 1230, Ptolemy's† system was translated from the Arabic into Latin: in this system the earth was supposed to be fixed in the centre of the universe, and that the Moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn, &c. moved round the earth.

But this unnatural and rude scheme was found incapable to stand the test of art and observation, and was, therefore, soon rejected by all true philosophers.

The Tychonic system, by Tycho, a noble Dane, succeeded the Ptolemean; in this the earth was supposed to stand still in the centre of the universe, and the sun to revolve about it every twenty-four hours, the planets, Mercury, Venus, Mars, Jupiter, Saturn,

* The Saracens, a people of Arabia, conquered Jerusalem in A. D. 637, Alexandria in 604, and entered Spain about 713.

† His proper name is Claudius Ptolemeus, and was born at Pelusium in Egypt, supposed to be descended from the Ptolemies, kings of Egypt.

&c. going round with the sun in the same period of time; and round the sun in their respective periods. This hypothesis, being partly true and partly false, was admitted by few, and soon gave way to the only true and rational system of Pythagoras, now restored by Nicholas Copernicus, a famous astronomer of Polish Prussia, and published about the year 1543. This system was demonstrated by Sir Isaac Newton, and established on such a firm basis as is not likely to be overturned.

Sir Isaac, by his wonderful genius, has discovered the fountain and source of all the celestial motions, and the great and universal law which governs and actuates the whole, and which is diffused through infinite space.

This inherent principle, which the All-wise Creator has implanted in all bodies, and commanded them to observe; this universal law of attraction and motion, not only keeps the planets and comets within their limits, but also every object in the universe, and prevents them from traversing irregularly the regions of unlimited space. The annexed representation of the true Pythagorean, Copernican, Newtonian, or Solar System, with the succeeding epitome, will show more exactly its principles.

CHAP. V.

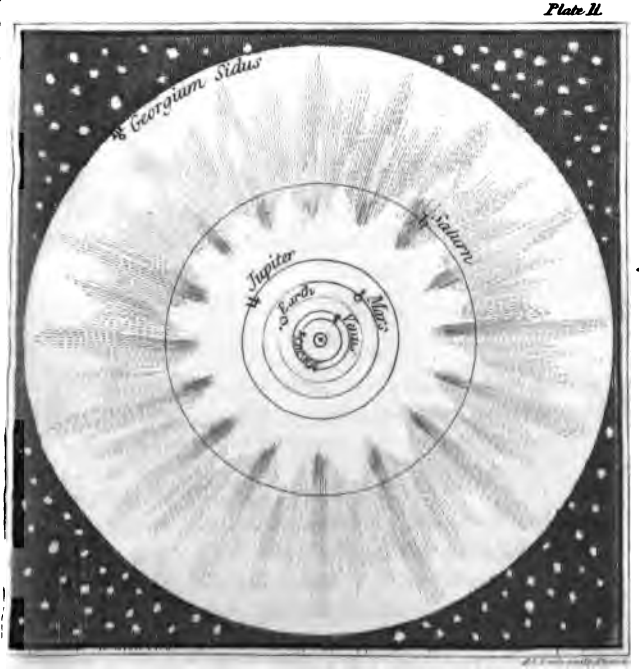
An Epitome of the Solar System, the Characters used in Astronomy, the Magnitudes of the Stars, the Greek Letters, Asteroides, Comets, the Chief Divisions of the Heavens, Constellations, &c.

It has already been observed, that a thorough knowledge of geography was necessary, before entering on the problems of the terrestrial globe; it appears likewise proper to observe in this place, that some knowledge of astronomy should be obtained, previous to entering upon the problems of the celestial globe.

But as a regular study of astronomy is more intricate, and less common, than geography, it is presumed that few, to whom this system of the globes is addressed, have an opportunity of acquiring it; in order, therefore, to furnish the young pupil with the outline, and to induce him to pursue this branch with more accuracy, a small epitome of the solar system is here presented. ¶

A Representation of
THE SOLAR SYSTEM.

Plate II.



Engraved for Greig's use of the Globes.

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CHARACTERS USED IN ASTRONOMY.

☉	Represents the Sun	♅	Repr. Georgium Sidus
☽	.. Moon	☊	.. Dragon's Head (Nodes)
⊕	.. Earth	☋	.. Dragon's Tail (Nodes)
☿	.. Mercury	☌	.. Conjunction
♀	.. Venus	✶	.. Sextile, or 60° (Aspects)
♂	.. Mars	□	.. Quartile, 90° (Aspects)
♃	.. Jupiter	△	.. Trine, or 120° (Aspects)
♄	.. Saturn	☍	.. Opposition, 180° (Aspects)

1. THE SUN, ☉, an immense globe of fire, is placed near the common centre or lower focus * of the orbits † of all the planets, and turns round his axis in 25 days 14 hours, which is known by the spots seen on his sur-

* If a thread be tied loosely round two pins stuck in a table, and stretched by the point of a black-lead pencil carried round by an even motion and light pressure of the hand, an oval, or ellipsis, will be described; the two points where the pins are fixed being called the foci thereof, or its centres.

† Orbit of the earth, planets, &c. is their path round the sun, it is in the form of an ellipsis; the sun is placed in or near to the lower focus of each of them. The points where the orbits of the planets, &c. intersect the ecliptic are called their nodes. Mars, Jupiter, Saturn, and the Georgium Sidus, are called superior planets, because they are highest in the system, and their orbits without that of the earth; Mercury and Venus are called inferior planets, because their orbits are within that of the earth.

face, that arise at one side and disappear at the other regularly. Whether he moves in an orbit has not yet been determined, although, agreeable to the apparent order of things in the universe, there is much reason to conclude that he has a revolution, but of such extent, as to require many ages to determine. His diameter is 890,000 miles and is about 1,400,000 times larger than the earth, and contains 8,911,000,000 square miles on his surface.

2. MERCURY, ☿, the nearest planet to the sun, from which he is distant about 36,841,000 miles, performs his revolution round the sun in about 88 days, which is the length of his year; the length of his day is unknown; his diameter is 3,200 miles, and his hourly motion in his orbit 105,000 miles, contains 21,236,800 square miles on his surface; he is generally so near the sun, as seldom to be seen with the naked eye; through a good telescope he exhibits the various phases of the moon, except that he never appears full; his heat and light is seven times more than on the earth in summer.

3. VENUS, ♀, is the second planet from the sun, from which she is distant 68,891,000 miles, and performs her revolution in about 224¾ days, which is the length of her year, and turns on her axis in 24¼ of our days, which is her natural day; her diameter is 7,699 miles, she contains 691,361,300 square miles on her surface, and, when viewed through a telescope, ex-

hibits the various phases of the moon: her hourly motion in her orbit is 69,000.

Venus is easily known by her whiteness and brightness, which exceeds that of all the other planets; being sometimes so considerable as to cause a shadow. When she rises before the sun, she is called the Morning Star, and when she sets after him is called the Evening Star.

4. The EARTH, ⊕, the third planet from the sun, from which it is nearly distant 95,173,000 miles, performs its revolution round the sun in 365 days, 5 ho. 49 min. 57 sec.; its diameter is 7,940 miles, and turns on its axis from W. to E. in twenty-four hours; its hourly motion in its orbit is 68,000 miles, besides which, the inhabitants on the equator are carried after the rate of 1,042 miles per hour, and those on the parallel of London, where a degree of longitude is 43½ miles English, 648 miles by its diurnal motion, exclusive of its annual motion in its orbit. The earth is an oblate spheroid that is flattened at the poles; its equatorial diameter being 37 miles, nearly, longer than its polar diameter. It is surrounded by a thin, fluid body, called the atmosphere, which is calculated to be sufficiently dense at 44 miles height to reflect the rays of the sun. The earth's axis is inclined 23½° to the axis of its orbit.*

* The best modern astronomers are generally agreed, that

5. The MOON, ☽*, is not a primary planet, but a satellite, or an attendant to the earth, from which she is distant about 240,000 miles, and distant from the sun 95,173,000 miles: she performs her revolution round the earth, from change to change, in 29 days, 12 hours, 44 minutes, and turns on her axis in the same time; which is the reason that the same side appears always to us, and hence from one half of the moon the earth is never seen: she goes round the sun with the earth every year, or 365 days, 5 hours; her diameter is 2,180 miles, and is equal to about $\frac{1}{4\frac{1}{8}}$ part of the earth.

the angle which the ecliptic makes with the equator is continually decreasing, at the rate of about one minute in a hundred years; and, therefore, if the earth continues in existence and this diminution continues, the two circles will, in 140,000 years coincide, and the days and nights will, for a long time, about that period, be equal throughout the earth, except at the poles, where there will be constant sunshine for many years.

* A most correct and ingenious representation of the face of the moon has been drawn by that able artist Mr. Russell, a bare inspection of which would almost convince the most incredulous, that the moon is inhabited similar to this earth: nor is there any reason to doubt, that all the heavenly bodies are likewise inhabited. That point of the orbit of the moon, or planets, wherein they are nearest to the earth, is called their perigee, the opposite point, in which they are farthest off, is called their apogee.

6. MARS, ♂, is the fourth planet in the order from the sun, from which he is 145,000,000 miles distant: he performs his revolution in his orbit in about 687 days, which is the length of his year, and turns on his axis in 24 hours 40 minutes, being the length of his natural day; his diameter is 5,400 miles, his surface contains 62,058,240 square miles, moves in his orbit at the rate of 55,287 miles an hour, his quantity of light and heat is equal to one half of ours, and the sun appears half as large to him as to us. Mars' appearance in the heavens is that of a fiery red.

7. JUPITER, ♃, is the fifth planet from the sun, and the largest in the system, distant from the sun 494,991,000 miles; he performs his revolution in his orbit in 11 years, 314¾ days, and turns on his axis in about 10 hours, which is the length of his natural day; his diameter is 89,069 miles, he moves in his orbit 29,000 miles an hour, and contains 20,603,970,000 square miles on his surface; the difference between his polar and equatorial diameter is upwards of 6,000 miles. Jupiter has four moons,* and is besides surrounded by three faint substances, called belts; he is about 1,400 times larger than the earth.

* The eclipses of Jupiter's satellites, or moons, afford an infallible method of determining the velocity of light, which is

8. SATURN, ♄, the sixth planet from the sun, from which he is about 907,956,000 miles distant, performs his revolution in 29 years 174 days nearly, which is the length of his year; his diurnal motion, according to Dr. Herschel, is 10 hours 16 minutes; his diameter is 77,950 miles, and contains 960 times our earth; his surface is equal to 14,102,562,000 miles, and hourly motion in his orbit is about 22,000 miles.

Saturn has seven moons, and is likewise surrounded with two lucid rings, 21,000 miles broad, which is equal to their distance from him.

9. The HERSCHELITE, or GEORGIUM SIDUS, ♅, discovered by Dr. Herschel, astronomer to his Majesty, in 1781, is the seventh planet from the sun; and according to M. de Lalande, is about 1,800,000,000 miles distant from him, and performs his revolution in about 83 years, being the length of his year; his diurnal motion is unknown; his diameter is 35,109 miles, and hourly motion in his orbit is 37,000 miles;

found to be about 11,500,000 miles in a minute; the smallness of its particles preventing its having any material effect on our eyes: the minuteness of its parts will appear from the calculation given by Dr. Niewentyt, that in a second of time there flows from a lighted candle 418 septillions, and 660 thousand sextillions particles of light.

six moons have been discovered attending him: he is seldom seen with the naked eye.

M. Piazzi, of the university of Palermo, in the island of Sicily, discovered a new planet in January 1781, situated between Mars and Jupiter, which he denominated, in compliment to the king of Naples, CERES FERDINANDIA. This planet resembles the planet Mars, and by Dr. Herschel is supposed to be about 163 miles in diameter, and distant from the sun 250,000,000 of miles; its revolution is 4 years and 122 days; and can only be seen with a good teleseope.

In March, 1802, Dr. Olbers, of Bremen, in Germany, discovered another small planet, likewise situated between Mars and Jupiter, which he named PALLAS; its light is pale and white, and by Dr. Herschel is estimated to be 93 miles in diameter.

On the 1st of September, 1804, M. Harding, of Lilienthal, discovered another small planet, situated between Mars and Jupiter, which he named JUNO.

Dr. Olbers, in March, 1807, discovered a small planet, also situated between Mars and Jupiter, which he named VESTA. But no particulars have yet transpired relating to these planets, that can be depended on.

The four last planets are by Dr. Herschel called ASTEROIDS, because they differ in many respects from the planets and comets.

COMETS, of which there are supposed to be 450 connected with the solar system, are solid, opaque bodies, with long transparent tails issuing from the side that is contrary to the sun. The most noted of the comets appeared in December 1680, which Sir Isaac Newton computed to be, when nearest to the sun, 2,000 times hotter than a red-hot iron; and that, being so heated, would require 20,000 years to cool; its period of return is computed to be 575 years, and, therefore, is expected to appear in the year 2255. This comet, at its greatest distance from the sun's centre, is 11,200,000,000 miles, and at its least distance 49,000 miles, being within less than a third part of the sun's semi-diameter from his surface.

In that part of its orbit, nearest to the sun, it flies at the amazing swiftness of 880,000 miles in an hour; and the sun, as seen from it, appears 40,000 times larger than he appears to the inhabitants of this earth.

The comet which appeared in 1532 and 1661, whose revolution was supposed to be performed in 129 years, should have accordingly again appeared in 1790; but this not happening, shows that the theory of comets is not yet well ascertained, which may be deduced, not only from their periods proving irregular, but from the various directions in which they move; nor does it seem sufficiently clear, that they belong to the solar system, but rather that they are links that join our system to others, and thereby keep up a regular motion

amongst systems, and may be considered as active agents diffused through infinite space. Nor does this notion of comets derogate from the law of gravity, as is evident from their retaining their natural elliptical path, when near the sun, as well as when beyond the known limits of his system: by the same inherent principle, they may enter the neighbouring systems, and advance as near to their centres, and return by a power similar to that which they left us. A comet appeared at London in the autumn of 1807, passing in a NE. direction, through Hercules Kneeling, Lyra, and Cygnus. Another very brilliant comet appeared at London, about the end of August 1811; when first seen, it was near the hinder feet of Ursa Major, it passed through Canes Venatici, Bootes, Corona Borealis, Hercules, Anser, Aquila and Antinous; on the south of the latter constellation, it disappeared in January 1812.

Fixed Stars are so called, because they have generally been observed to keep at the same distance from each other. They are at such an immense distance as not to appear the least improved in their magnitude by a telescope that magnifies 6,500 times. They are supposed to be suns in the centres of their respective systems, having planets revolving round them the same as our sun, and likewise to shine with their own light as he does.

From what is known of the immense distance of the stars, the nearest of them may be computed at the dis-

tance of 32 billions of miles, which is farther than a cannon-ball would fly in 7,600,000 years, admitting it to move at the rate of eight miles per minute.

The stars, on account of their apparent magnitudes, are divided into classes: those which appear largest, are of the first class or magnitude; the next to them in lustre, of the second magnitude; and so on to the sixth, which are the smallest visible to the naked eye.

The stars are commonly represented in the following manner:

 Represents Stars of the 1st Magnitude.

 2d mag.

 3d mag.

 4th mag.

 5th mag.

 6th mag.

Stars less than the 6th magnitude are not visible without a telescope, and are therefore called telescopic stars. But although the stars are commonly represented as above, it is necessary to observe, that there is no general mode whereby they are expressed, either on the globes, or in works of astronomy.

The magnitudes of the stars, taking them in general, as they appear in the starry firmament, are distinguished by the number of rays; but in the constellations on

the globes, they are specified by the Greek letters; that is, the first letter of the Greek alphabet (α) is placed by the largest star in the constellation, whatever magnitude it is of; the second letter (β) by the second in lustre, continuing in this progressive manner through the alphabet; and the remainder of the stars in the constellation (if any), are specified by a succession of the Roman alphabet, beginning with the first as in the Greek; and if there still remain some stars unmarked, then the numbers 1, 2, 3, &c. are applied. The method of marking the stars by letters was introduced by John Bayer, of Augsburgh, in Swabia, in a work entitled *Uranometria*, published in 1603.

The Greek Alphabet.

	Name.	Sound		Name.	Sound.
Α α	*Alpha*	*a* short	Ν ν	*Nu*	*n*
Β β ϐ	*Beta*	*b*	Ξ ξ	*Xi*	*x*
Γ γ ϝ	*Gamma*	*g*	Ο ο	*Omicron*	*o* short
Δ δ	*Delta*	*d*	Π π ϖ	*Pi*	*p*
Ε ε	*Epsilon*	*e* short	Ρ ρ ϱ	*Rho*	*r*
Ζ ζ ζ	*Zeta*	*z*	Σ ϲ σ ς	*Sigma*	*s*
Η η	*Eta*	*e* long	Τ τ ⊺	*Tau*	*t*
Θ ϑ θ	*Theta*	*th*	Υ υ	*Upsilon*	*u*
Ι ι	*Iota*	*i*	Φ φ	*Phi*	*ph*
Κ κ	*Kappa*	*k*	Χ χ	*Chi*	*ch*
Λ λ	*Lambda*	*l*	Ψ ϕ	*Psi*	*ps*
Μ μ	*Mu*	*m*	Ω ω	*Omega*	*o* long

The small letters only are used on the celestial globe; the capitals are here introduced by way of form.

The ancients divided the starry sphere into constellations, according as they lay contiguous to one another, so as to occupy those spaces which the figures of different animals or things would take up, if they were there delineated.

This division of the stars serves to distinguish them from one another, so that any particular star may be easily found in the heavens by means of a celestial globe.

The heavenly bodies are apportioned into three principal divisions; containing ninety-four constellations.

1. The zodiac, in which are twelve constellations, commonly called the twelve signs of the zodiac.

2. All that space of the heavens which lies on the north side of the zodiac, and which contains thirty-five constellations.

3. The regions south of the zodiac, which contain forty-seven constellations.

The names of the constellations, the number of stars that each contains, and their position on the globe, will appear more concisely in the following table.

NORTHERN CONSTELLATIONS.

No.	Names in Astronomy.	English Names.	No. of Stars.
1,	Ursa Minor, at the N. pole	The Little Bear	24
2,	Ursa Major	The Great Bear	87
3,	Draco	The Dragon	80

No. Names in Astronomy.	English Names.	No. of Stars.
4, Cepheus	Cepheus	35
5, Böotes	The Herdsman	54
6, Corona Borealis, by Böotes	The Northern Crown	21
7, Hercules	Hercules Kneeling	113
8, Lyra	The Harp	21
9, Cygnus	The Swan	81
10, Cassiopeia	The Lady in her Chair	55
11, Perseus et Caput Medusa	Perseus	59
12, Auriga	The Waggoner	66
13, Serpentarius	The Serpent Bearer	74
14, Serpens	The Serpent	64
15, Sagitta, N. of Aquila	The Arrow	18
16, Aquila	The Eagle	71
17, Antinous	Antinous	
18, Delphinus	The Dolphin	18
19, Equulus	The Horse's Head	10
20, Pegasus	The Flying Horse	89
21, Andromeda	Andromeda	66
22, Triangulum	The Triangles	16
23, Cameleopardalis	The Cameleopard	58
24, Leo Minor	The Little Lion	53
25, Coma Berenices	Berenice's Hair	43
26, Vulpecula et Anser	The Fox and Goose	35
27, Lacerta, E. of Cygnus	The Lizard	16
28, Scutum	The Shield	7

No.	Names in Astronomy.	English Names.	No. of Stars.
29,	Asterion et Chara	...The Greyhounds	25
30,	Lynx	The Lynx	44
31,	Cerberus, by Hercules	Cerberus	4
32,	Mons Mænalus, N. of Libra	The Mountain Mænalus	11
33,	Taurus Poniatowski E. of Serpentarius	The Bull of Poniatowski	7
34,	Musca, SW. of Perseus	The Fly	6
35,	Tarandus, by the N. pole.	The Rein Deer	12
	Total number of Stars in the Northern regions		1448

THE SIGNS OF THE ZODIAC.

No.	Names in Astronomy.	English Names.	No. of Stars.
1,	Aries ♈	The Ram	66
2,	Taurus ♉	The Bull	141
3,	Gemini ♊	The Twins	85
4,	Cancer ♋	The Crab	83
5,	Leo ♌	The Lion	95
6,	Virgo ♍	The Virgin	110
7,	Libra ♎	The Scales	51
8,	Scorpio ♏	The Scorpion	44
9,	Sagittarius ♐	The Archer	69
10,	Capricornus ♑	The Goat	51
11,	Aquarius ♒	The Water-bearer	108
12,	Pisces ♓	The Fishes	113
		Stars in the Zodiac	1016

SOUTHERN CONSTELLATIONS.

No.	Names in Astronomy.	English Names.	No. of Stars.
1,	Cetus	The Whale	97
2,	Orion	Orion	78
3,	Eridanus	The River	84
4,	Lepus, S. of Orion	The Hare	19
5,	Canis Major	The Great Dog	31
6,	Canis Minor	The Little Dog	14
7,	Argo Navis	The Ship	64
8,	Hydra	The Hydra	60
9,	Crater, S. of Virgo	The Cup	31
10,	Corvus, by Hydra	The Crow	9
11,	Centaurus	The Centaur	35
12,	Lupus	The Wolf	24
13,	Ara, S. of Scorpion's Tail	The Altar	9
14,	Corona Australis	The Southern Crown	12
15,	Piscis Australis, SW. of Sagittarius	The Southern Fish	24
16,	Columbi Noachi, by Canis Major	Noah's Dove	10
17,	Robur Carolinum	The Royal Oak	12
18,	Grus	The Crane	13
19,	Phœnix	The Phœnix	13
20,	Indus	The Indian	12
21,	Pavo	The Peacock	14
22,	Apus Avis Indica, within the antarctic circle	The Bird of Paradise	11

No.	Names in Astronomy.	English Names.	No. of Stars.
23,	Apis Musca	The Bee, or Fly	4
24,	Chameleon, at the S. pole	The Cameleon	10
25,	Triangulum Australis, on the antarctic circle	The South Triangle	5
26,	Piscis Volans	The Flying Fish	8
27,	Dorado, at the S. pole of the ecliptic	The Sword Fish	6
28,	Toucan	The American Goose	9
29,	Hydrus	The Water Snake	10
30,	Sextans, S. of Leo	The Sextant	41
31,	Monoceros	The Unicorn	31
32,	Crux, by Centaurus	The Cross	5
33,	Officina Sculptoria, S. of Cetus	The Sculptor's Apparatus	12
34,	Circinus, E. of Centaurus	The Compasses	7
35,	Brandenburgium Sceptrum, S.W. of Orion	The Sceptre of Brandenburg	13
36,	Equuleus Pictorius, near the S. pole of the ecliptic	The Painter's Easel	8
37,	Fornax Chemica, by Cetus	The Chemist's Furnace	14
38,	Horologium, S. of Eridanus	The Clock	12

No.	Names in Astronomy.	English Names.	No. of Stars.
39	Mons Mensa, near the S. Pole	The Table Mountain...	30
40,	Machina Pneumatica, N.E. of Argo Navis	The Air Pump	24
41,	Norma Euclidis, E. of Lupus	Euclid's Square	12
42,	Octans Hadleianus, at the S. pole	Hadley's Quadrant ...	43
43,	Pyxis Nautica, in the rigging of Argo Navis	The Mariner's Compass	8
44,	Recticula Rhomboidalis, antarctic circle	The Rhomboidal Net...	10
45,	Telescopium, ...	The Telescope	9
46,	Cela Praxitelis, W. of Argo Navis	The Engraver's Tools	16
47,	Microscopium, E. of Sagittarius	The Microscope	10

Total number of Stars in the Southern regions 1019

Stars in the Northern constellations 1443
—— in the Zodiac 1016
—— Southern constellations 1019

Total number visible by a telescope 3478, forming 94 constellations.

The above constellations may, in some measure, agree with the number commonly found on globes; but it appears, that the discovery of stars keeps pace with optical improvements; for on Bardin's 18-inch globes there are depicted upwards of 6000 stars, clusters, planetary, nebulæ, &c. To enter into a particular description of these would exceed the limits of a Treatise on the Globes, we shall therefore conclude with the words of Dr. Herschel and M. De Lalande; "In passing rapidly over the heavens with his new telescope, the universe increased under his eye; 44,000 stars, seen in the space of a few degrees, seemed to indicate that there were 75,000,000 in the heavens." *Memoirs of the Academy at Dijon*, 1785.

The same idea is corroborated by Dr. Herschel, as may be seen in the Philosophical Transactions. "In the most crowded parts of the Milky Way, he has had a field of view of 588 stars, and these continued for many minutes; so that in 15 minutes not fewer than 116,000 stars have passed through the field of his telescope."

CHAP. VI.

ECLIPSES.

EVERY planet and satellite is illuminated by the sun, and casts a shadow towards that point of the heavens which is opposite to the sun. This shadow is the privation of light in the space hid from the sun by the opaque body that intercepts his rays.

An eclipse of the moon happens only when she is full, and is produced by the moon's passing through the shadow of the earth: which occurs when the earth is in a direct line between the sun and moon. If the light of the sun be kept off from the whole body of the moon, it is a total eclipse; if from a part only, it is a partial one, and is expressed by the number of digits* that are darkened.

An eclipse of the sun, is when the moon, being in a right line between the sun and the earth, hinders the light of the sun from coming to us, and happens at the change only. If the moon hide from us the whole body of the sun, it is a total eclipse; if not, it is a partial one: when the moon changes at the greatest distance from the earth, its dark shadow terminates

* Digits. See note, Prob. xxxviii. Terrestrial globe.

in a point before it reaches the earth, and, to those immediately under it, the sun's edge appears like a luminous ring all round the body of the moon, and is called an annular eclipse.

Besides the dark shadow of the moon, there is another fainter one, which encompasses it, called the penumbra, which exhibits different degrees of shadow upon those parts which are only partially deprived of the sun's rays.

The greatest dark shadow of the moon covers only a spot on the surface of the earth, equal to about 180 English miles broad; but the penumbra, or partial shadow, may cover a space equal to 4900 miles diameter, and, if it falls obliquely on the earth, it stretches out into an elliptical form. An eclipse of the moon begins always on the eastern side, and of the sun on the western side.

The number of eclipses in any year of both luminaries cannot be fewer than two, nor more than seven; the most usual number is four, and it is very uncommon to have more than six. Eclipses of the sun are more frequent than those of the moon, because the sun's ecliptic limits are more extensive than the moon's; but we have more visible eclipses of the moon than the sun, because eclipses of the moon are seen from all parts of that hemisphere of the earth which is next them, and are equally great to each of those parts; but the sun's eclipses are

visible only to that small portion of the hemisphere where the moon's shadow falls.

An occultation is when a star is hid from our sight by the moon or a planet.

CHAP. VII.

THE CELESTIAL GLOBE.

DEFINITIONS.*

THE artificial celestial globe is a representation of the heavens, on which are placed the fixed stars in their natural position and magnitude.

When the globe is turned round upon its axis, it represents the apparent diurnal motion of the sun, moon, and stars. The pupil, in using this globe, is to imagine it transparent and himself in the centre of it, whence he can view the stars in their natural position, as in one vast concave.

1. Latitude of a star or planet, is its distance from

* As the definitions of most of the lines, &c. on the terrestrial globe accord with those of the celestial, in order to avoid a repetition, we shall here only take notice of those more immediately connected with celestial objects.

the ecliptic, north or south, measured on a great circle towards the pole of the ecliptic. The sun has no latitude, being always in the ecliptic.

2. Longitude of a star or planet, is its distance from Aries, reckoned eastward quite round the globe; hence extends to 360 degrees on the ecliptic. The longitude of the sun on the celestial globe is the same as what is called the sun's place on the terrestrial globe.

3. Right ascension of the sun or stars, is that part of the equinoctial which rises or sets with the sun or star when the globe is in the position of a right globe, or sphere, reckoned from Aries eastward round the globe, being 360°.

4. Oblique ascension of the sun or stars, is that part of the equinoctial which comes to the meridian with the sun or star, in an oblique globe or sphere, and is reckoned on the equinoctial, from Aries, quite round the globe eastward, being likewise to 360°.

5. Ascensional difference of the celestial objects, is the difference between their right ascension and oblique ascension, and, likewise, it is the time that the sun rises or sets before or after six.

6. Equinoctial points,* are where the ecliptic crosses the equator, viz. at Aries and Libra.

* Precessions of the equinoxes is a gradual motion which the equinoctial points have from east to west, contrary to the

7. The solsticial points, are where the ecliptic touches the tropics, viz. at Cancer and Capricorn.

8. The poles of the ecliptic, are where the celestial meridians meet, and are the same to the ecliptic as the poles of the earth are to the equator. The pole of the ecliptic, on the celestial globe, is $23\frac{1}{2}°$ from the pole of the equator.

9. Declination of the sun or stars, is their distance from the equator north or south. The sun's greatest declination is $23\frac{1}{2}°$, but the greatest declination of the stars extends to the poles, being 90°.

order of the signs, which is from west to east. This motion, from observations, is found to be about $50\frac{1}{4}$ seconds in a year, so that in the space of 25,791 years the celestial objects make an entire revolution westward round the globe, found by dividing the seconds in 360° by $50\frac{1}{4}''$.

In the time of Hipparchus, the equinoctial points were fixed in Aries and Libra, but the signs that were then in conjunction with the sun, when he was in the equinox, are now 30° eastward of it, so that Aries is now in Taurus, Taurus in Gemini, &c. Hence the stars that rose and set at any particular season of the year, in the times of Hesiod, Pliny, &c. do not answer to the description given of them by these writers.

CHAP. VIII.

Contains twenty-two Problems on the Celestial Globe; including the Phenomena of the Harvest Moon; Armillary Sphere, with Descriptions, &c.

PROBLEM I.*

The day of the month being given, to find the sun's right ascension, or the right ascension of a star.

BRING the sun's place for the given day, or the star to the meridian, then the degree cut by the meridian on the equator, reckoning from Aries eastward, is the ascension required.

Given the 20th of March; required the sun's right ascension for that day? Answer, 0.

What is the sun's right ascension on the 23d of July? Answer, 122° 10′.

Required the sun's right ascension on the 26th of September? Answer, 185° 30′.

* Problems i. xiv. xv. xx. xxvii. xxviii. and xxxii. on the terrestrial globe, being common to both globes, it is not necessary to repeat them among the Problems of the celestial.

PROBLEM II.

A place and its latitude, day and month being given, to find the sun's oblique ascension and descension.

Rectify the globe for the latitude, bring the sun's place to the eastern verge of the horizon; then the degree of the equinoctial, cut by the east part of the horizon, is the sun's oblique ascension; turn the globe till the sun's place come to the western verge of the horizon, and the degree cut by it on the equinoctial, reckoning from Aries in both cases, will be the sun's oblique descension for the given day.

Given London, the 20th of March; required the sun's oblique ascension and descension? Answer, the sun being on the equator, and in the first degree of Aries, has neither ascension nor descension.

What is the sun's oblique ascension and descension at London on the 23d of July? Answer, his oblique ascension is 95°, and oblique descension 150°.

Required the sun's oblique ascension and descension at London, on the 27th of September? Answer, oblique ascension is 187°, and oblique descension 182° 30′.

PROBLEM III.

*A place and its latitude given, to find the sun's ascensional difference.**

Find, by the preceding problems, the sun's right and oblique ascension; subtract the less from the greater, and the remainder is the sun's ascensional difference.

Given London, 21st of May; required the sun's ascensional difference? Answer, 29° 15′=1 hour, 57 minutes.

Required the sun's ascensional difference at Cape Horn, in latitude 55° 58′ S. on the 21st of December? Answer, 40°=2 ho. 40 mi.

Required how long the sun rises before, or sets after six, on the 20th of September at London? Answer, seven minutes before or after six=1° 45′.

* It has already been observed, that the sun's ascensional difference is the time that he rises or sets before or after six; therefore can only be applied in N. latitude, during the six months in which the sun passes from Aries to Libra; and in S. latitude during the time in which the sun advances from Libra to Aries, through the southern signs. By this problem, the length of the day can be found, if the hour-circle was wanting.

PROBLEM IV.

*A place and its latitude, day and month being given, to find the sun's amplitude.**

Elevate the pole to the given latitude, bring the sun's place to the eastern verge of the horizon, then the number of degrees between the sun's place and the east point on the horizon is his amplitude at rising, which is likewise equal to his amplitude at setting.

Given London, the 20th of March; required the sun's amplitude? Answer, 0.

Required the sun's amplitude at rising and setting at Lisbon, lat. 38° 42′ N. on the 23d of July? Answer, 26° N. of the east and west points.

What is the sun's amplitude at setting or rising at London on the 21st of June? Answer, 40° N. of the E. at rising, and 40° N. of the W. at setting.

* Amplitude of the sun, is an arch of the horizon, comprehended between the true east or west points thereof, and the centre of the sun at his rising or setting.

PROBLEM V.

*The latitude and month given, to find the sun's azimuth.**

Rectify the globe for the latitude, fix the quadrant in the zenith, mark the sun's place for the given day, and bring it to the meridian; set the index to the upper XII, turn the globe till the index points to the given hour, and fix it; bring the graduated edge of the quadrant to the sun's place, then the number of degrees, reckoned on the azimuth circle of the horizon, between the quadrant and the south or north point, is the azimuth required.

Given London, 21st of May, at nine A. M.; required the sun's azimuth? Answer, 69° from the south point.

Required the sun's azimuth at London, the 23d of August, at four P. M.; Answer, 75° from the south point.

What is the sun's azimuth at latitude 38° 42′ N. on the 21st of June, at six A. M.? Answer, 70° from the north point.

* Azimuth, is the true distance of the sun or star from the north or south points of the compass, at any time of the day.

PROBLEM VI.

The latitude of a place, day of the month, and hour of the night being given, to find the sun's depression below the horizon.

Rectify the globe for the given latitude, bring the sun's place for the given day to the meridian, and set the index to the upper XII, turn the globe till the index points to the lower XII, mark the sun's place that is under the meridian, turn the globe till the index points to the given hour, and fix it; screw the quadrant over the given latitude, and bring its graduated edge to the sun's place: then the number of degrees between the sun's place and the horizon, shown by the quadrant, is the sun's depression at the time required.*

Given latitude 51° 30′ London, the 21st of June; required the sun's depression below the horizon at midnight? Answer, 15°.

Required the sun's depression below the horizon at midnight at London, the 21st of December? Answer, 62°.

* If the time given be midnight, then rectify the globe, and bring the sun's place to the meridian under the horizon, and the number of degrees, reckoned on the meridian, between it and the horizon at the elevated pole will be the depression required.

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point, and in the eastern hemisphere? Answer, six o'clock in the morning.

PROBLEM VIII.

*The latitude, day of the month, and the altitude of any known star, with the hemisphere it is in, being given, to find the hour of the night.**

Rectify the globe for the latitude, fix the quadrant in the zenith, bring the sun's place to the meridian, and set the index to the upper XII, move the globe and quadrant till the star's centre coincide with the altitude on the quadrant, and the index will point to the hour.

Given 51° 30′ N. lat. the 28th of December, and Regulus in Leo, (♌), altitude 40° in the western hemisphere: required the hour of the night? Answer, a little past six in the morning.

Observed at London, the 19th of February, that the Pleiades were in the eastern hemisphere, and had 20°

* If the star is on the meridian, that is due south or north, its altitude can be reckoned on the brass meridian. The proper motion of the earth being from west to east, causes the heavenly objects to make an apparent retrograde motion from east to west.

of altitude; required the hour? Answer, 11 ho. 35 mi. A. M.

What hour is it at London, on the 30th of October, when Aldebaran in the Bull has 10° of altitude in the east side of the meridian? Answer, 7 hours 45 minutes, P. M.

PROBLEM IX.

To find the latitude and longitude of any given star.

Bring the pole of the ecliptic, that is in the hemisphere with the given star, to the meridian; screw the quadrant over it, and fix the globe; bring the graduated edge of the quadrant over the star, then the number of degrees between the ecliptic and star is the latitude, and the degrees between the quadrant and Aries, reckoned eastward on the ecliptic, is the longitude.

Given Atair, in Aquila north constellation, required its latitude and longitude? Answer, latitude 29° 30′, longitude 299° 30′.

Required the latitude and longitude of Arcturus in Bootes? Answer, latitude 31°, longitude 202° 30′.

What is the latitude and longitude of Fomalhaut in the South Fish? Answer, lat. 21°, long. 331.

*A Table of the mean right Ascension in Time, Declination, and Names of 20 of the most remarkable Fixed Stars, calculated for 1804, and will serve for many Years.**

	Names of Stars.	Right Asc. ho. mi. sec.	Declination. ° ′ ″
1	Almak in Andromeda's Foot.....	1 51 51	41 23 — N
2	Algol, Medusa's Head	2 55 27	40 11 27 N
3	Aldebaran, in Taurus.....	4 24 40	16 6 13 N
4	Capella, in Auriga.....	5 2 14	45 46 18 N
5	Rigel, Orion's Foot	5 5 7	8 26 44 S
6	Betelgeux, Orion's Shoulder.....	5 44 44	7 21 48 N
7	Sirius, Canis Major	6 36 30	16 27 20 S
8	Castor, in Gemini	7 22 4	32 19 26 N
9	Pollux, in Gemini	7 33 18	28 30 29 N
10	Procyon, in Canis Minor	7 29 2	5 44 20 N
11	Regulus, Lion's Heart	9 57 55	12 57 37 N
12	Dubhe, Ursa Major ..,.....	10 51 31	62 51 — N
13	Atair, in Aquila.....	19 40 39	8 19 54 N
14	Arcturus, in Bootes	14 39 53	20 25 24 N
15	Markab, in Pegasus	22 55 —	14 9 15 N
16	Pleiades, in Taurus	3 45 13	23 27 24 N
17	Antares, in Cor Scorpio,.....	16 17 25	25 58 55 S
18	Fomalhaut, South Fish	22 46 47	30 41 47 S
19	Lyra, in the Harp.....	18 30 18	38 36 38 N
20	Polar Star, Ursa Minor.....	— 47 57	88 12 10 N

* The greatest annual variation of the above stars, in their right ascension, is less than 5″, which will not amount to a fourth of a degree in 180 years. The greatest annual difference in their declination is less than 20″, which will not amount to the fourth of a degree in 45 years.

PROBLEM X.

Any star being given, to find its declination, or distance from the equator north or south.

Bring the star to the meridian, then the degrees between the star and equinoctial, reckoned on the meridian, is the declination required.

Given Procyon in the Little Dog, (Canis Minor); required its declination? Answer, 5°, 44′ N.

Required the declination of Arcturus, in Bootes, the Herdsman? Answer, 20° 25′ N.

What is the declination of Aldebaran, in the Bull? Answer, 16° 6′ N.

PROBLEM XI.

Any star being given, to find its right ascension.

Bring the given star to the meridian, then the degree cut by the meridian on the equinoctial, reckoning from Aries, is the ascension required.

Given Almak, in Andromeda; required his right ascension? Answer, 1 ho. 52. mi.=28°.

Required the right ascension of Regulus in Leo? Answer, 9 ho. 58 mi.=149° 30′.

What is the right ascension of Sirius, in Canis Major, the Great Dog? Answer, 6 ho. 36 mi.=99°.

PROBLEM XII.

The day of the month and right ascension of any star being given, to find the time the star comes to the meridian.

Bring the sun's place to the meridian, set the index to the upper XII, then bring the degree answering to the right ascension of the given star, or the star to the meridian, and the index will point to the time that the star culminates, or comes to the meridian.

Given the 21st of March, and the right ascension of Aldebaran, 4 ho. 25 mi.; required the time of its culminating? Answer, at 25 mi. past four in the afternoon.

Required at what o'clock Regulus will be on the meridian on the 23d of September, his right ascension being 9 ho. 58 mi.=149° 30′? Answer, 9 ho. 50 mi. A. M.

What time will Sirius, in the Great Dog, be on the meridian on the 1st of December, his right ascension being 6 ho. 36 mi.? Answer, at a quarter past two o'clock in the morning.

PROBLEM XIII.

The right ascension and declination of a star being given, to find the star on the globe.

Bring the degree of the star's right ascension, on the equinoctial to the meridian, and under its declination, on the meridian, is the star required.

Given 7 ho. 22 mi. = 110° 30′ ascension, and 32° 19′ N. declination; required the star? Answer, Castor in Gemini (the Twins).

Required what star has 5 ho. 2 mi.=75° 30′ ascension, and 45° 46′ declination N.? Answer, Capella, in Auriga.

If a certain star has 6 ho. 36 mi.=99 right ascension, and 16° 27′ S. declination, what is its name? Answer, Sirius in the Great Dog, (Canis Major.)

PROBLEM XIV.

The latitude of a place, day of the month, and star being given, to find the time of its rising, being on the meridian, and setting, the point of the compass that it rises and sets on, and its duration above the horizon.

Rectify the globe for the latitude given, bring the sun's place to the meridian; set the index to the

upper XII, bring the star to the eastern side of the horizon; observe what point of the compass coincides with it, which is its bearing at the time of its rising, and the index will show the time that it rises. Bring the star to the meridian, and the index will show the time of its southing, then to the western verge of the horizon, which will show the point it sets on, and the index will point to the time of its setting, the time between which and its being on the meridian being doubled, shows its duration above the horizon.

In latitude 51° 30′ N. the 29th of November, given Pollux, in Gemini; required the time of its rising, being on the meridian, setting, the points of the compass that it rises and sets on, and duration above the horizon? Answer, rises NE. by N. ½ E. at 6 ho. 15 mi. P. M. on the meridian, 3 ho. 15 mi. A. M.; sets 2 mi. past noon, NW. by N. ½ W.; duration above the horizon, 17 ho. 50 mi.

Given 51° 30′ N. the 21st of December, and Antares, in Scorpio; required the time of its rising, setting, &c.? Answer, rises SE. at 6 ho. 50 mi. in the morning, on the meridian 10 ho. 20 mi.; sets SW. at 50 mi. past one P. M.; duration above the horizon 7 ho.

Required the time of rising, setting, &c. of Aldebaran, in Taurus, on the 20th of January, lat. 51° 30′ N.? Answer, rises 45 mi. past noon, on the meridian, at a quarter past eight in the evening, and sets

45 mi. past three in the morning; duration above the horizon 15 ho.; rises NE. by E $\frac{1}{2}$ E., sets NW. by W. $\frac{1}{2}$ W.

PROBLEM XV.

*To find the distance between two given stars.**

Bring one of the stars to the meridian, fix the quadrant over it, and bring the graduated edge of the quadrant over the other star, and the number of degrees between them reckoned on the quadrant is the distance required.

Given Fomalhaut, in Piscis Australis, (the Southern Fish), and Achernar in the River Eridanus, south constellation; required their distance? Answer, $39\frac{1}{2}°$.

Required the distance between Lesath, in the Scorpion's Tail, marked on the globe λ, and Spica Virginis, in Virgo? Answer, 61°.

How far is Dubhe, in the back of Ursa Major, (the Great Bear), from Castor in Gemini (the Twins)? Answer, 44° 30′.

* If the given stars are on the same meridian on the ecliptic or equinoctial, the number of degrees between them, reckoned on these lines, is the distance required.

PROBLEM XVI.

The day of the month being given, to find all those stars that will be on the meridian at noon and midnight of that day.

Bring the sun's place for the given day to the meridian; set the index to the upper XII, then the stars that are under the meridian are south or north at noon; turn the globe till the index points to the lower XII, and those under the meridian will be south or north at midnight.

Given London, the 30th of June; required what stars are on the meridian at noon and midnight? Answer, at noon Canopus in the ship; Sirius, Procyon, Castor and Pollux, are the nearest; the midnight line passes near Lyra in the Harp, over the South Crown, &c.

Required what principal stars are on the meridian, at noon and midnight on the 19th of February, at any part of the earth? Answer, at noon, the first degree of Pisces, Fomalhaut, Markab in Pegasus, Alderamin in Cepheus, &c. at midnight, the Pointers in Ursa Major, Alkes in the Cup, the bright star in the Oak, &c. are nearly at the meridian.

What principal stars are on the same meridian with the sun on Christmas day, and what stars on the meri-

dian at midnight? Answer, the meridian at noon passes over the South Crown, Sobieski's Shield, Lyra, &c. at midnight, over near Sirius, Betelgeux in Orion, &c.

PROBLEM XVII.

The latitude being given, to find what stars never rise, and what stars do not set in that latitude.

Rectify the globe for the given latitude; turn the globe quite round, observing, at the same time, what stars, at the elevated pole, do not pass under the horizon, which are those that never set in the given latitude; turn the globe round again, and observe what stars do not come above the horizon, which are the stars that never rise in that latitude.

NOTE. On the equator, all the stars in the firmament rise and set.

Required what stars never rise in latitude 51° 30′, London, and what stars never set there?

A bit of chalk held to the co-latitude of the place, on the globe's being turned round, will describe a circle containing all those stars that never set, and if held to the opposite point, that is at the same latitude in the opposite hemisphere, it will describe a circle containing all the stars that never rise in that latitude.

PROBLEM XVIII.

The latitude, day of the month, and hour being given, to place the globe so as to represent at that time the upper hemisphere of the starry firmament, and thereby to find the relative situation and names of the most remarkable stars, with the constellations that they are in.†*

Place the globe north and south in the open air, (where no interruption is made by various objects,) by a compass placed on the pedestal, or horizon, allowance being made for the variation of the needle, (see Problem I. Ch. III.) Rectify the globe for the given lat., bring the sun's place to the meridian, and fix the globe, then the globe represents the stars in the same position that they are in the heavens at the

* Mr. Benjamin Martin justly observes, that this problem, of itself, is sufficient to recommend the use of the celestial globe to every studious and rational mind.

† In this case, if a conical piece of wood was placed with its base on any star, the sharp end would point to the corresponding star in the heavens; or, suppose the eye placed in the centre of the globe, and holes pierced through the place of the stars on its surface, the eye would observe the corresponding stars in the firmament, and hence the stars and constellations might be known by their names.

noon of the given day; set the index to the upper XII, and turn the globe to the hour given, which will represent the position for that time. Turn the globe to any hour, and fix it, and each time will exhibit the position of the stars at the respective hours.

Given lat. 51° 30′ N. London, 24th of October; required what principal stars are on the meridian at the noon of that day, at nine in the morning, 3, 5, 6, and 10 at night, and also what principal stars are above the horizon at the given times respectively?

Given latitude 55° 30′ N. 8th of September; required the appearance of the celestial objects at the noon and midnight of that day, and at 2 A.M. 3, 5, 8, 11, &c. P.M.?

PROBLEM XIX.

*The latitude, day of the month, and the moon's place in her orbit being given, to find the time of her rising, being on the meridian, and setting.**

Rectify the globe for the latitude given, bring the sun's place to the meridian, and set the index to the

* The moon and planets make a constant variation and shifting of their places in the zodiac, therefore the problems in which they are concerned cannot be performed by a globe,

upper XII; bring the moon's place to the eastern verge of the horizon, then to the meridian, and to the western verge of the horizon; and the index, at the first place will show the time of her rising, at the second her time of being on the meridian, and at the third her time of setting.

Given lat. 51° 30′, 1st of June, the moon's place 12° 19′ in Pisces (♓), lat. 3° N.; required the time of her rising, being on the meridian, and setting?

without the help of an Ephemeris, by which their places are found; the most convenient for this purpose is that calculated by Robert White, and published by the Stationers Company, price 2s. 8d. stitched, which serves likewise for an almanack. The moon moves, or increases her longitude, in the ecliptic, at a mean rate about 13° every day, (in the Ephemeris; it is calculated to noon,) therefore an allowance, after the rate of nearly half a degree for each hour in her semi-diurnal arch, is to be made, to find her place at rising and setting; in the former case it is to be subtracted from her place at noon, and in the latter case it is to be added; this circumstance is considered in the above solutions of of the moon.

The moon's or planets' places in their orbits are found on the globe thus: find their places in the ecliptic by their longitude, taken from the Ephemeris for the given day; and observe that through each degree of the ecliptic are drawn lines perpendicular to it, and that these are crossed at right angles with other lines, each one degree apart; therefore the moon's or planet's place in its orbit is, where the line, passing through its longitude, intersects that of its latitude, either north or south.

Answer, rises 30 mi. past midnight, on the meridian at 15 mi. past 6, and sets at noon.

At London the 25th of December, the moon in 22° 26′ in Libra (♎), lat. 5° 14′ S.; required the time of her rising, southing, and setting? Answer, rises at 2 in the morning, on the meridian at 7, and sets at 50 mi. past 11.

When the moon is in 1° of Aquarius (♒), and 4° lat. N. and the sun in 14° 15′ of Sagittarius, (♐), in lat. 51° 30′ N.; required her time of rising, southing, and setting? Answer, rises at 35 mi. past 10 A.M. on the meridian 15 mi. past 3, and sets at 10 mi. past 8 at night.

PROBLEM XX.

The latitude, day of the month, and any planet with its latitude and longitude being given, to find its place on the globe and the time it rises, is on the meridian, and sets.

Rectify the globe for the latitude given, bring the sun's place to the meridian, and set the index to the upper XII, find the place of the planet by its latitude and longitude, and mark it; bring it to the eastern verge of the horizon, and the index will point to its time of rising; bring it to the meridian, and to the

western verge of the horizon, and the index will point at the first place to its being on the meridian, and at the second to its time of setting.

Given London, lat. 51° 30′, 20th of January, Jupiter (♃), lat. 1° N. lon. 2° 30′ in Scorpio (♏); required the time of his rising, being on the meridian, and setting? Answer, rises at one in the morning, on the meridian at 6, and sets at 11 A.M.

Required the time of the rising, southing, and setting of Venus (♀), at London, 1st of September, her lon. being 4° 12′ in Leo (♌), and lat. 6° 15′ S.? Answer, rises at half past two in the morning, on the meridian 40 mi. past 9, and sets 55 mi. past 4 A.M.

What hour does Mars (♂) rise, south, and set at London, on the 22d of December, his lat. being 2° N. and lon. 19° 5′ in Leo (♌)? Answer, rises at 8 ho. 8 mi. P.M., on the meridian 3 ho. 35 mi. A.M., and sets at 11 A.M.

PROBLEM XXI.

To trace on the globe the moon's path for any number of given days, hence to find what stars the moon will approach near to, or eclipse.

Find from an Ephemeris the moon's place for the noon of each day given, on which lay patches, then

place the quadrant of altitude, or a thread, over these patches, which will point out nearly the path of the moon in her orbit, and consequently the stars that lie in or near to it?

Required what principal stars lie in or near the moon's path on the 1st, 2d, 3d, 4th, and 5th days of October, 1804?

	°	′			°	′	
Oct. 1st, moon's lon.	12	2	♍	lat.	3	12	S.
... 2d, ...	24	43	...	...	3	59	
... 3d, ...	7	13	♎	...	4	33	
... 4th, ...	19	33	...	...	4	54	
... 5th, ...	1	44	♏	...	5	1	

These places being found on the globe, and the quadrant laid over them, will show that the moon's path passes over the first of Leo, and near to Regulus, Spica, &c.

NOTE—That the paths of the planets may be found after the same manner; but as they move slower in their orbits, the periods for which their places are taken from the Ephemeris must be farther apart; likewise the orbit, or path of a comet may be found by the globe, by marking as above its places, taken from several observations, at different periods, and the quadrant placed over them will point out the path.

PROBLEM XXII.

*The phenomenon of the harvest moon explained.**

This phenomenon appears about the time of the full moon that happens when the sun is near to the autumnal equinox, when she rises for some nights, before and after the full, nearly at the same time, on account of the horizon being nearly parallel to that part of her orbit through which she is then passing.

The contrary appearance happens at the vernal equinox, a considerable time then elapsing between the setting of the sun and rising of the full moon.

Rectify the globe for the latitude given, find the moon's place in the ecliptic from the Ephemeris, and her place in the orbit (by the note at Problem XIX.) for some days preceding the full and after it, and mark each place. Bring the sun's place for each day to the meridian, and set the index to the upper XII, turn the globe until the moon's place, corresponding

* The advantage of moon-light, arising from this phenomenon, is not however the same every year, of which the following is a specimen: in 1804, 1805, and 1806, it is more beneficial than in 1807, 1808, 1809, 1810, 1811, 1812, 1813, 1814, 1815; then a period of ten years succeeds, in which it is again more beneficial, viz. from 1816 to 1825, inclusive.

to each day, come to the verge of the eastern horizon, and the index will point to the time of rising on the respective days.

To exhibit this phenomenon for September, 1804; full moon happens on the 19th, therefore the moon's place in the ecliptic must be found from the Ephemeris, and from that and her latitude her place on the globe, for the 18th, 19th, 20th, 21st, and 22d days, and are as follow:

Sept. Sun's place.	*Moon's lon.*	*Moon's lat.*	*Time of rising.*
☉ ′	☾ ° ′	☾ ° ′	ho. mi.
18...25 19 ♍	... 10 11 ♓	... 3 2 N.	 P. M.
19...26 18	 24 20	 3 57	
20...27 16	 8 48 ♈	... 4 38	6 2
21...28 15	 23 38	 5 1	6 24
22...20 14	 1 11 ♉	... 5 4	6 46

ARMILLARY SPHERE.

The *Artificial Sphere* represented in the annexed plate, consists of a number of metallic circles, representing the chief circles of the globe, viz. the brass meridian, the horizon, zodiac, tropics, polar circles, &c. in their natural order, and as they appear to the eye; serving to direct the idea of the use and disposition of each, to assist the imagination in understanding

Armillary Sphere.



the constitution of the heavens, and the motion of the celestial orbs.

There are two sorts of this instrument, the *Ptolemean*, and the *Copernican;* the former of which is here exhibited, and is disposed according to the Ptolemean hypothesis, that is, with the earth fixed in the centre, and the other parts so ordered as to revolve round it, whereby the sun's diurnal and annual course about the earth is shown, according to that hypothesis; and in the manner that one unacquainted with astronomy might conceive.

It is named from *Armilla*, in Latin, signifying a bracelet for the arms, because the circles or rings of which it is composed, resemble that ornament.

The *Copernican Sphere* has the earth placed near the circumference, but this sort is less common than the other, and more intricate in its application.

This sphere differs from the common globe, by its having the circles represented simply, the globe having also the intermediate spaces between the circles.

CHAP. IX.

GEOGRAPHICAL THEOREMS.*

1. The latitude of any place is always equal to the elevation of the pole at the same place.

2. Places on the equator have no latitude; places on the first meridian have no longitude, consequently where the first meridian crosses the equator there is neither longitude nor latitude.

3. Places under the poles have the greatest latitude, and places on opposite meridians the greatest longitude.

4. Places north or south of the equator have their latitudes greater, or less, as they are distant from it. Places east or west of the first meridian have their longitudes greater, or less, according as they are distant from it.

5. The sensible horizon changes to any object as often as that object shifts its position.

6. All places on the earth enjoy, naturally, the same length of the light of the sun, and consequently

* Theorem signifies a proposition which searcheth out and expresses some acknowledged truth, or general property of a figure or thing.

are equally deprived of it, except what is produced by refraction.*

7. On the equator, the days and nights are always of equal length.

8. In all parts of the earth, except under the poles, the days and nights are equal, that is twelve hours, when the sun is on the equator.

9. At all places on the earth, except on the equator and at the poles, the days and nights are never equal, except when the sun is in the first degree of Aries and Libra.

* Refraction of the celestial objects, is the height that they appear to us more than they are, and is produced by the rays of light falling on the atmosphere, which, being denser, bends them and makes the object from whence they come appear higher than it is. The denser that the atmosphere is, the refraction is the greater, the sun sometimes appearing above the horizon 10 minutes before he rises and after he sets, and at a mean rate 6 minutes; and this is likewise the cause of twilight. The inhabitants near the poles enjoy by this a larger share of twilight, as also more sun and moonshine, than those in places of less latitude.

A remarkable instance of refraction is recorded of some Dutchmen, who wintered in Nova Zembla, in 1596, in latitude 76° N. who were surprised to find, after a continual night of three months, the sun began to appear seventeen days sooner than they expected, according to computation.

10. At all places situated on the same parallel of latitude, the days and nights are of the same length.

11. All places in the torrid zone have the twilight shortest, those in the frigid zones longest, and in the temperate zones a medium between the other two.

12. To all places in the torrid zone the sun is vertical twice a year, to those on the tropics once, but never to those in the temperate and frigid zones.

13. To all places in the frigid zone, the sun continues above the horizon, without setting, for a certain number of days, and disappears for the same space of time, which is more or less in proportion as the place is distant from, or nearer to the pole, where it is the longest, being equal, without refraction, to six months.

14. At all places between the equator and the arctic circle, the longest day and shortest night are, when the sun has the greatest north declination, that is, when he is in the first degree of Cancer; and the shortest day and longest night, when he has the greatest declination south, that is, when he comes to the first degree of Capricorn.

15. On the equator, objects cast their shadow six months northerly and six months southerly, except the two days of the year that the sun is in the equinoctial; then objects have no shadow at noon; the former are called Amphiscii, and the latter Ascii.

16. Objects at all places in the temperate zones have their noon-day shadow all one way, and are called Heteroscii.

17. In the frigid zones the shadows are directed to all the points of the compass, and are called Periscii.

18. If a ship sets out from any port, and sails round the earth, eastward, to the same port again, the reckoning of that ship's time will exceed the time kept at the port by one day, whether the voyage be long or short; and if they sail westward round the globe, they will be one day less in their reckoning than those at the port. This theorem may be illustrated, by supposing a person to travel westward, keeping pace with the sun, quite round the earth, it is evident that he will have constant day; but the people at the port will have had night during his absence, and will therefore naturally reckon one day more than he does; the contrary will happen if he travels eastward, at the same rate.

19. Therefore, if two ships sail from the same port and at the same time, and both sail round the earth, the one to the eastward and the other to the westward, on their return to the port that they set out from, they will differ two days in their reckoning, supposing them to return on the same day. If they sail twice round in the same manner, they will differ in their reckoning four days, &c.

20. But if two ships sail from the same port, at the

same time, and one sails due north and the other due south, and return to the port at the same time, the reckoning of the ships and those at the port will be the same.

CHAP. X.

TWENTY-FOUR PARADOXES.

1. THERE are two places on the earth, remarkable for their having only one day and one night in the year.

Solution. The places are the north and south poles of the earth.

2. There is a particular place on the earth, where the wind always blows from the north; also another place on the earth, where it blows constantly from the south.

Solution. These places are likewise at the north and south poles of the earth; at the north pole every part of the earth lies south, there being no east or west at the poles; therefore, not only the wind, but every object on the earth, are to the southward, and the contrary at the south pole.

3. There are passages over several rivers in Europe of such a breadth, that 10,000 men could pass over abreast without any inconvenience.

Solution. This may be understood of a common bridge, as the men could pass over it sideways, and in that case will be abreast; or more properly, over rivers that run a considerable way under ground, of which there are several, as the Mole, in Surrey; the Allen, in Flintshire, Wales; and the Guadiana, in Spain.

4. There is a certain European island, the south end of which often changes its latitude and longitude.

Solution. Any island that floats, (of which there are several small ones, particularly in a lake near St. Omer's, in the department of the Strait of Calais,) must change its latitude and longitude, not only at the southward, but every part of it.

5. There are certain islands situated between England and France, and yet England is nearer to France than they are.

Solution. England is only 21 miles from France, at Dover; the Isle of Wight, and several islands on the coast of Hampshire, lie between England and France, but more than 21 miles from France.

6. There is a certain place on the earth, that if 100 men set out from thence on one hundred meridians, they would all be under the necessity of travelling due north.

Solution. This can be no other place than the south pole, from which all places bear north.

7. There is a tract of land on the earth, 10 miles in length, and so situated, that a person travelling from one end of it to another, must first go 5 miles north, and, without turning, go 5 miles south.

Solution. This tract of land must be at the north pole, which pole is in the middle of it, hence a person having gone 5 miles, and arrived at the pole, must in the next 5 miles go south, whether he turns or not.

8. There are twenty places on the continent of Europe, each 12 miles apart, hence equidistant as you pass from the one to the other, yet it is impossible to bring any more than two of them in a straight line, at a time.

Solution. They must be in a circle; and not only in Europe, but in any country.

9. There are nineteen places on the earth that lie under the same meridian, and are exactly 18 miles apart, yet are so situated that it is impossible for them to be all equally distant.

Solution. Any two places, not adjacent to one another, must be more distant than those that are adjacent, and it is evident that the first and last places are farthest apart.

10. There is a famous church in Great Britain, situated in such a manner, that a man may travel 300 miles without being farther or nearer to it.

Solution. This may be expressed of any church or place, not only in Great Britain, but every where; as a person going round it on a circle, may walk any number of miles without being farther or nearer to it.

11. There is a city in the kingdom of Bengal, in the East Indies, so situated that the sun is 3,000 miles nearer to it at noon, than at rising or setting.

Solution. The same may be said of any city, or place on the earth, as the sun is the semidiameter of the earth, which is more than 3,000 miles nearer to any place at noon, than at his rising or setting.

12. There are two places on the earth, so situated, that the sun is always on the meridian.

Solution. These places are the north and south poles of the earth.

13. There are two remarkable places on the earth where the sun, moon, planets, stars, and the vane that points to the wind, are constantly in a line on the meridian.

Solution. These places are likewise the poles of the earth, as all objects there seen must always be on the meridian.

14. There are various places in Great Britain and Ireland, and the English colonies, where the stars are always visible, if the atmosphere is not overcast.

Solution. At any place and time on the earth, the stars may be seen through a good telescope, if the air is clear.

15. There is a certain place of the earth, where, if two ponderous weights were to meet, a person might place his hand between them without any danger of being hurt, and if a fire was made there, the flame and smoke would circle round it without flying off; and if a plain table was placed there, and water poured on it, the water would not run off, but rise up in a heap.

Solution. This place must be at the centre of the earth, where gravity is supposed to be so equally divided as to cease.

16. There is a remarkable place of the earth, near Ispahan, in Persia, of that strange quality, that it is impossible for two of the sincerest friends to continue in the same for one minute.

Solution. It may be deduced from the smallest reflection, that two friends, or two objects of any description, cannot occupy the same place at the same time, therefore holds good in every place as well as Ispahan.

17. There are four places of the earth, so situated that they are all equally distant from one another.

Solution. The four places must be situated in the position of the points of a solid triangle, of equal sides, therefore three of the places must be in the earth, and one on its surface ; or three may be on its surface and one in it; and likewise may be determined by three of the places being on the earth, and one up above it.

18. There is an island on the coast of Britain, where

the body of the sun and moon is visible before they rise and after they set.

Solution. This is true at any place of the earth, and arises from refraction, which raises all the heavenly bodies, and makes them appear higher at all times than they are, but more so at rising and setting, which sometimes extends to 10 minutes, a sufficient length of time to make them visible some time before they begin to rise and after they set.

19. There is a certain circle on the earth, on which if a man walk any distance, his head will pass over more space than his feet, and his feet will uniformly meet more resistance than his head.

Solution. It is evident, from the globular form of the earth, that wherever a person walks, it must be on a circle, and as his head is farther from the centre of the circle, (that is, the centre of the earth,) it must pass through more space; and as the atmosphere is denser at the surface of the earth than above it, his feet must meet greater resistance from it.

20. There is a large town in Britain, that is neither in Scotland nor England, and the air is of that peculiar quality, that the moon appears always most enlightened when she is absolutely least so, and least enlightened when she is most so.

Solution. This holds good, with respect to the moon, in every town and place on the earth, because

when the moon is full she appears most enlightened, but it is known she is least so ; as she is then all the breadth of her orbit, which is 480,000 miles, farther from the sun than at the change, when she seems least enlightened. With respect to the town being in neither country, may be said of Berwick-upon Tweed, which is partly in England and partly in Scotland, the river Tweed, which separates the countries, passing through it.

21. There are certain places in the vicinity of London, not forty-feet broad, where a man might travel 100 miles, but in such a situation, that one of his feet must pass through more space than the other.

Solution. This may be understood of not only places near London, but any where on a circle ; a person may go round it to any length of space, and it is evident, that the foot next to the outer side must go faster than the one next the centre, and therefore pass through a longer extent of space.

22. There is a spacious plain near Seringapatam, in the Hither Peninsula of the East Indies, where an army of 90,000 men could be drawn up in battle array ; but it is of that nature, that if they were drawn up, yet it would be impossible for any two of them to stand (naturally) parallel to one another.

Solution. The same may be said of any plain, or

part of the earth, as, from its globular form objects placed perpendicular to the plane of the horizon cannot be parallel to one another, their heads being farther apart than their feet; therefore the walls of a house, the pillars of an entry, &c. are not parallel to each other; and may be compared to the spokes in the nave of a wheel.

23. There is a place of the earth, where the most ponderous weight would support itself, without the assistance of any substance whatever.

Solution. This place must be at the centre of the earth, where gravity ceases. Suppose a passage made from one side of the earth, through the centre, to the other side, and a weight dropped through it, after several vibrations, it would settle at the centre, and hang suspended without any support, there being no attraction to draw it away.

24. There are certain places on the earth, where, if men were placed at each of them, those at some of the situations would pass through thousands of miles more than those at the other places, in one day, without their leaving the position that they were placed in.

Solution. Some of them may be placed at or near the poles, others at or near to the equator, then those near the poles would experience some thousands of miles less of the diurnal motion of the earth than those near the equator.—NOTE. Objects on the equator are

carried 25,008 miles in a day by the earth's diurnal motion, while at the poles they are only affected by the earth's motion in its orbit.

THE APPLICATION, BY QUESTION AND ANSWER, TENDING TO PROMOTE A PRACTICAL REVIEW OF THE WHOLE.

CHAP. XI.

1. QUESTIONS RELATING TO THE TERRESTRIAL GLOBE.

1. Required which of the poles is raised, and how much, when the globe is rectified for the Cape of Good Hope? Answer, the south pole is elevated 34° 26′.

2. What is the latitude and longitude of Lima, in South America? Answer, 12° 1′ S. latitude and 76° 40′ W. longitude.

3. Given a place in latitude 55° 41′ N. and longitude 12° 46′ E.; required the place? Answer, Copenhagen, in Denmark.

4. Required what places have the same latitude as the city of Naples, in Italy?

Turn the globe quite round, and all the places that

pass under 40° 51′ N. lat. have the same latitude as Naples.

5. Given Jeddo, the capital of the empire of Japan; required its antœci? Answer, at lat. 36° 10′ S. and lon. 139° 30′ E. in the Pacific Ocean.

6. In what latitude and longitude are the periœci of Bristol? Answer, 51° 29′ N. lat. and 177° 24′ E. lon. amongst the Aleouskie Islands, N. Pacific Ocean.

7. Required the antipodes of Cape Horn, the south point of America? Answer, at 55° 58′ N. lat. and 112° 40′ E. lon. in Siberia.

8. What is the difference of latitude between Quebec in Canada, and Moscow in Russia? Answer, 8° 50′.

9. Required the difference of longitude between Dublin and Cape Comorin, the south point of the Hither Peninsula in the East Indies? Answer, 84° 59′.

10. Given two places on the same meridian, one in 20° N. lat. and the other in 30° S. lat.; required their distance in miles English? Answer, 3475 miles.

11. Required the distance between two places in lat. 20° N. or S., one place being in 2° 15′ W. and the other 15° 45′ E. lon.? Answer, 1175½ English miles, 1014¾ geographical miles.

12. What is the greatest distance that any two places can be apart on the earth? Answer, 180° = 10800 geographical miles = 12,510 English miles.

13. Given Edinburgh; required the bearing of Archangel on the White Sea? Answer, NE. by an angle of position.

14. Required the sun's place in the ecliptic on the 8th of September? Answer, 16° Virgo ♍.

15. What day of the month is the sun in the 1° of Aries? Answer, 20th of March.

16. What is the difference of time between London and any place in 80° lon. east or west? Answer, 5 ho. 20 mi.

17. When it is noon at York, what o'clock is it at Corinth in ancient Greece? Answer, 36 minutes past one in the afternoon.

18. Required the time that the sun rises and sets, and the length of the longest day, at Dungsby Head, in lat. 58° 45′ N. (being the northernmost point of Great Britain,) on the 21st of June? Answer, the sun rises at 2 ho. 51 mi., sets at 9 ho. 9 mi., length of the day 18 ho. 18 mi., night 5 ho. 42 mi.

19. In lat. 51° 30′; required the length of the longest day and shortest night? Answer, the longest day is 16 ho. 34 mi., and shortest night 7 ho. 26 mi.

20. Required at what latitude the day is always 12 hours? Answer, on the equator.

21. When does twilight end and bègin, at London on the 19th of October, and what is its duration? Answer, begins 4 ho. 55 mi.; ends 7 ho. 5 mi.; duration 1 ho. 54 mi.

22. At what place will the sun be vertical on Christmas day, when it is noon at London? Answer, in the South Atlantic, nearly in a line between St. Helena and the Cape of Good Hope.

23. Required at what places the sun will be vertical at their noon, on the 29th of September.

Turn the globe quite round, and all those places that come under 2° 30′ S. which is the sun's declination for the given day, will have the sun vertical at their noon.

24. Given Borneo, in the island of Borneo; required what two days of the year the sun is vertical there, its latitude being 4° 55′ N.? Answer, the 2d of April and the 10th of September.

25. Given London, 21st of December at noon; required to what countries the sun is rising, setting, noon, and midnight? Answer, the sun is rising at the Gulf of St. Lawrence, Cuba, New Spain, &c.; noon at London, west side of France, through Algiers, &c.; and setting at Delhi, the west side of China, &c.

26. Required the sun's meridian altitude at Rome on the 23d of August? Answer, 59° 34′.

27. What is the altitude of the sun at Archangel, lat. 64° 34′ N. on the 21st of December at noon? Answer, 1° 58′.

28. Place the globe so as to find the hour of the day, by the hour-circle, when the sun shines.

29. Required on what point of the compass the sun rises and sets, at London, on the 19th of February? Answer, rises ESE. $\frac{1}{4}$ E. nearly, and sets WSW. $\frac{1}{4}$ W. nearly.

30. Whether are the clocks or sun fastest, at London, on Lady-day, and how much? Answer, the clocks are 5 mi. 59 sec. before the sun by the table, and 2 mi. 10 sec. by the globe.

31. Required on what day of the month the longest day begins, ends, and duration, at the bottom of Baffin's Bay, lat. 80° N.? Answer, begins the 15th of April; and ends the 27th of August; duration 134 days.

32. What climate is latitude 85° in? Answer, the 30th.

33. Given the Azores; required what climate they are in? Answer, the 6th.

34. Given London and Canton in China, their distance 84° 30′; required what principal places are at the same distance from London? Answer, Cape Kennis in Japan, Bankoh in Siam, Cape Frio in the Brazils, &c.

35. Required what place in the latitude of 40° N. and lon. E. is 72° 30′ from London? Answer, Pekin in China.

36. Given London, and a place in W. lon. 59° 45′, distant 61°; required the place? Answer, Barbadoes.

37. A solar eclipse begins at London at 10 ho.

27 mi. A. M. on the 18th of February; required what countries it is visible to? Answer, Great Britain, Ireland, France, Spain, Portugal, the north parts of Africa, &c.

38. An eclipse of the moon happens at London on the 26th of January, begins at 7 ho. 57 mi. P. M.; required what countries it is visible in? Answer, Africa, Europe, Asia, the Indian Ocean, &c.

CHAP. XII.

2. RECAPITULATION OF THE CELESTIAL GLOBE.

1. Required the sun's right ascension on the first of December? Answer, 247° 30′=16 ho. 30 mi.

2. What is the sun's oblique ascension and descension at London, on the 2d of November? Answer, his oblique ascension is 237°, and oblique descension is 198°.

3. How much is the sun's ascensional difference on the 21st of June, or how long does he rise or set before or after six? Answer, rises 2 ho. 17 mi. before six, and sets 2 ho. 17 mi. after six.

4. Required the amplitude of the sun at London, on the 20th of April? Answer, 19½° N. of the E.

5. How far is the sun depressed below the horizon at London, on the 21st of December? Answer, 62°.

6. Given London, the 19th of February, at ten o'clock in the morning; required the sun's azimuth? Answer, 32° from the South point.

7. Given Rome, in latitude 41° 54′ N. the 22d of September, and the sun's azimuth 70° from the south point towards the east; required the hour of the day? Answer, 9 A. M.

8. In latitude 51° 30′ N. on the 1st of April, found Aldebaran's altitude to be 53° on the meridian; required the hour? Answer, 3 ho. 39 mi. A. M. that is, 3 ho. 39 mi. in the morning.

9. Given Markab in Pegasus; required its right ascension in time and degrees? Answer, 22 ho. 56 mi. = to 344°.

10. Required the declination of Aldebaran? Answer, 16° 6′ N.

11. Given Lyra in the Harp; required its latitude and longitude? Answer, latitude 61° 15′, longitude 13° ♑, or 283° from ♈.

12. Given the 20th of November, and the middle star in Orion's Belt; required what time it comes to the meridian of London? Answer, at 45 mi. past one in the morning.

13. Required what star has 9 ho. 57 mi. right ascension, and 12° 57′ N. declination? Answer, Regulus, Lion's Heart.

14. Given London, the 10th of September; required the time of the rising and setting of Sirius in

the Great Dog's Mouth? Answer, sets at noon, and rises 50 mi. past two in the morning.

15. Required the distance between Aldebaran in Taurus and the polar star? Answer, 73° 30′.

16. What is the distance between Denebalced, in the Lion's Tail, and Capella in Auriga? Answer, 85° 30′.

17. Required what stars never set at London?

18. What principal stars will be near the meridian of London at noon and midnight on the 12th of October? Answer, at noon the east foot of the Centaur, Spica in Virgo, Arcturus in Bootes, &c. at midnight, Achernar in Eridanus, Baten Kaitos in Cetus, Almak in Andromeda, &c.

19. Place the globe so as to represent the upper hemisphere of the starry firmament at London, on the 25th of December at midnight.

20. Given London; required the time that the moon sets on the 24th of October, when she is in the ecliptic and 1° of Scorpio? Answer, 5 ho. P. M.

CHAP. XIII.

3. QUESTIONS RELATING TO THE PARADOXES.

1. What places on the earth have only one day and one night in the year?

2. Required the two parts of the earth, where at one of them the wind blows always from the north, and at the other always from the south?

3. On what sort of passages could an army of 20,000 men pass abreast over a river?

4. How is it possible that any part of the earth can change its latitude and longitude?

5. Which way can the islands, that are situated between England and France, be farther from France than England is?

6. From what part of the earth is it, that those who set out from it are under the necessity of going due north?

7. Where is that tract of land situated, that, in going through part of it, one must travel first south and then north, without turning about?

8. In what position can twelve towns be situated that are equally distant from one another, and yet impossible to bring more than two of them in a line at once?

9. If ten places lie exactly in a line, each being six

miles apart from one another, which of them are farthest apart?

10. In what manner can a person travel some hundreds of miles, without being nearer or farther from a certain object?

11. What part of the earth is 3000 miles farther from the sun at his rising and setting than at noon?

12. Where is that place situated, that has the sun, moon, and stars, always on the meridian?

13. What remarkable place is that where the wind blows always from the point that the sun, moon, and planets are on?

14. Required the places where the stars are visible at noon, if the atmosphere is clear?

15. In what position can four objects be placed on the globe so as to be equally distant?

16. At what part of the earth does every thing lose weight, and cease to be affected by the daily motion of it?

17. Required what part of the earth has that peculiar quality of preventing two of the sincerest friends to occupy it?

18. Where is it, that the sun and moon are visible before they rise and after they set?

19. What country is that where the moon always appears most enlightened when she is least so, and least enlightened when she is most so?

20. Required where, on the earth, a man's head, in travelling, passes through more space than his feet?

21. How is it possible that a person can walk 80 miles in a place not 30 feet wide, and, by so doing, one of his feet moves uniformly quicker than the other?

22. What parts of the earth are so situated that two objects cannot stand parallel to one another, if placed perpendicular to the plane of the horizon?

23. At what parts of the earth will a ponderous body support itself without any assistance?

24. At what parts of the earth could two men be placed where one would uniformly move some thousands of miles, every day, more than the other?

ERRATA.

Page 26, *line* 9, *for* 93° *read* 90°; *p.* 59, *l.* 22, *for* odd miles, *r.* and odd miles; *p.* 72, *l.* 12, *for* sun-rise to sun-set, *r.* sun-set to sun-rise; *p.* 85, *under* January, *for* 22 58, *r.* 12 58; *and under* August, *for the four bottom numbers, r.* 4 2—2 57—1 40—0 14; *p.* 87, *l.* 3 *from the bottom, under* Climates, ends *is wanting*; *p.* 94, *l.* 10, *for* art, *r.* part; *p.* 109, *l.* 5 *from the bottom, dele* to.

FINIS.

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